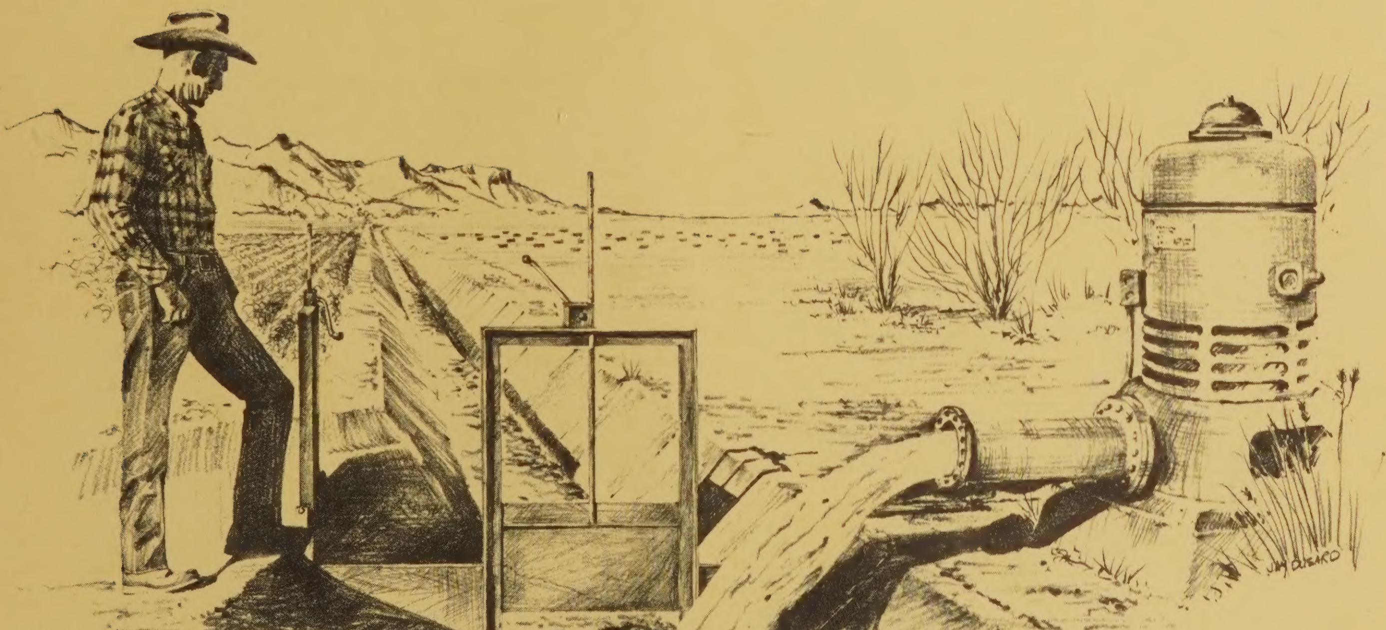
WATER-RESOURCES REPORT NUMBER TWENTY-FIVE
ARIZONA STATE LAND DEPARTMENT
OBED M. LASSEN, COMMISSIONER

AN APPRAISAL OF THE GROUND-WATER RESOURCES OF AVRA AND ALTAR VALLEYS PIMA COUNTY, ARIZONA

BY NATALIE D. WHITE
W. G. MATLOCK
AND H. C. SCHWALEN



PREPARED BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR
AND THE AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF ARIZONA

PHOENIX, ARIZONA
FEBRUARY 1966

ARIZONA STATE LAND DEPARTMENT WATER-RESOURCES REPORTS

The following reports are available for distribution at the Arizona State Land Department, 422 State Office Building, Phoenix, and at U. S. Geological Survey offices in: 232 Geology Building, University of Arizona, Tucson; and 5023 Federal Building, North First Avenue, Phoenix. Those marked with an asterisk (*) are out of print and are available on loan only from the U. S. Geological Survey, 232 Geology Building, University of Arizona, Tucson.

No.

* 1. Pumpage and ground-water levels in Arizona in 1955, by P. W. Johnson, N. D. White, and J. M. Cahill: 69 p., 30 figs., 1956.

* 2. Annual report on ground water in Arizona, spring 1956 to spring 1957, by J. W. Harshbarger and others: 42 p., 18 figs., 1957.

* 3. Geology and ground-water resources of the Harquahala Plains area, Maricopa and Yuma Counties, Arizona, by D. G. Metzger: 40 p., 2 pls., 7 figs., 1957.

* 4. Geology and ground-water resources of the Palomas Plain-Dendora Valley area, Maricopa and Yuma Counties, Arizona, by C. A. Armstrong and C. B. Yost, Jr.: 49 p., 3 pls., 4 figs., 1958.

* 5. Annual report on ground water in Arizona, spring 1957 to spring 1958, by W. F. Hardt, J. M. Cahill, and M. B. Booher: 60 p., 19 figs., 1958.

* 6. Annual report on ground water in Arizona, spring 1958 to spring 1959, by W. F. Hardt, R. S. Stulik, and M. B. Booher: 61 p., 18 figs., 1959.

* 7. Annual report on ground water in Arizona, spring 1959 to spring 1960, by W. F. Hardt, R. S. Stulik, and M. B. Booher: 89 p., 22 figs., 1960.

8. Geology and ground-water resources of the McMullen Valley, Maricopa, Yavapai, and Yuma Counties, Arizona, by William Kam: 72 p., 17 figs., 1961.

9. Hydrologic data and drillers' logs, Papago Indian Reservation, Arizona, by L. A. Heindl and O. J. Cosner, with a section on chemical quality of the water by L. R. Kister: 116 p., 3 figs., 1961.

*10. Annual report on ground water in Arizona, spring 1960 to spring 1961, by N. D. White, R. S. Stulik, E. K. Morse, and others: 93 p., 32 figs., 1961.

*11. Annual report on ground water in Arizona, spring 1961 to spring 1962, by N. D. White, R. S. Stulik, and others: 116 p., 35 figs., 1962.

No.

* 12A. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part I, Records of ground-water supplies, by G. E. Davis, W. F. Hardt, L. K. Thompson, and M. E. Cooley: 159 p., 3 figs., 1963.

* 12B. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part II, Selected chemical analyses of the ground water, by L. R. Kister and J. L. Hatchett: 58 p., 2 figs., 1963.

12C. Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Part III, Selected lithologic logs, drillers' logs, and stratigraphic sections, by M. E. Cooley, J. P. Akers, and P. R. Stevens: 157 p., 3 figs., 1964.

13. Desert floods—a report on southern Arizona floods of September 1962, by D. D. Lewis: 13 p., 18 figs., 1963.

*14. Basic ground-water data of the Willcox basin, Graham and Cochise Counties, Arizona, by S. G. Brown, H. H. Schumann, L. R. Kister, and P. W. Johnson: 93 p., 15 figs., 1963.

*15. Annual report on ground water in Arizona, spring 1962 to spring 1963, by N. D. White, R. S. Stulik, E. K. Morse, and others: 136 p., 47 figs., 1963.

16. Effects of ground-water withdrawal in part of central Arizona projected to 1969, by N. D. White, R. S. Stulik, and C. L. Rauh: 25 p., 7 figs., 1964.

17. Effects of ground-water withdrawal, 1954-63, in the lower Harquahala Plains, Maricopa County, Arizona, by R. S. Stulik: 8 p., 5 figs., 1964.

18. Basic ground-water data for western Pinal County, Arizona, by W. F. Hardt, R. E. Cattany, and L. R. Kister: 59 p., 4 figs., 1964.

19. Annual report on ground water in Arizona, spring 1963 to spring 1964, by N. D. White, R. S. Stulik, E. K. Morse, and others: 60 p., 27 figs., 1964.

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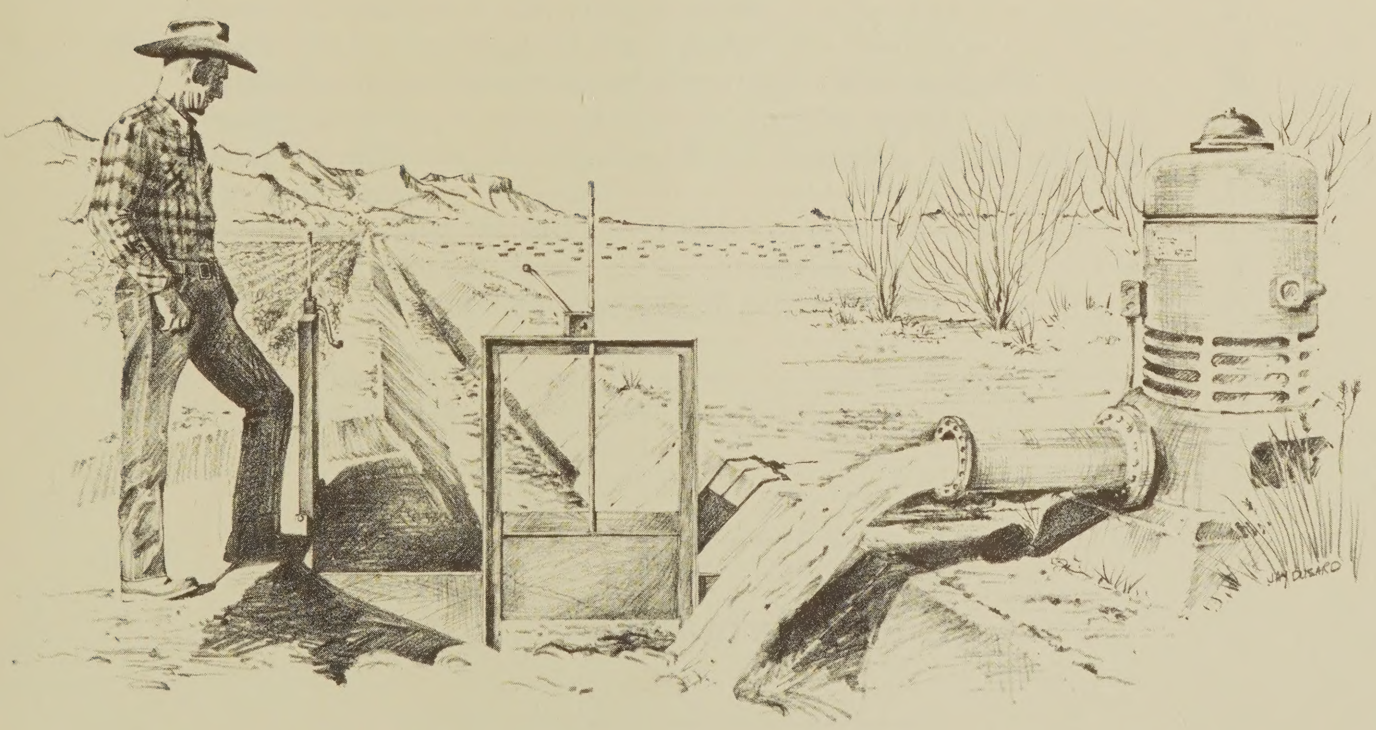

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AN APPRAISAL OF THE GROUND-WATER RESOURCES OF AVRA AND ALTAR VALLEYS, PIMA COUNTY, ARIZONA

By

Natalie D. White[1], W. G. Matlock[2], and H. C. Schwalen[3]

ABSTRACT

The U. S. Geological Survey has been collecting hydrologic and geologic data in the major irrigated basins of Arizona for many years as part of a statewide ground-water survey. The Agricultural Engineering Department, Agricultural Experiment Station, University of Arizona, has been collecting data in parts of the State for nearly an equal period of time. The work of the Geological Survey is done mainly in cooperation with the Arizona State Land Department, Obed M. Lassen, Commissioner; that of the Agricultural Engineering Department is in cooperation with the city of Tucson and Pima County. For several years, the results of the statewide ground-water survey have been presented in the annual reports on ground water in Arizona. In recent years, the volume of data collected has increased, and the need for a comprehensive analysis of the data also has increased along with the growing demand for water. This is the third in a series of reports by the Geological Survey on individual basins, and it is the first report prepared in conjunction with the Agricultural Engineering Department of the University of Arizona. The reports present a more detailed study of the hydrologic and geologic data than is feasible in the annual reports covering the entire State.

Avra and Altar Valleys are in the central part of Pima County in southern Arizona. The two valleys are separated by an arbitrary dividing

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line perpendicular to Brawley Wash in Tps. 15 and 16 S., and Avra Valley extends northward to the Pima-Pinal County line.

The climate of the valleys is arid, which results in the evaporation of a large part of the precipitation before it can be used beneficially. Almost no surface water is available for man's use in the area; all the streams are ephemeral, and Altar and Brawley Washes, the principal drainage features, are subject to large-scale flooding at times. The only water supply in the area comes from the ground-water reservoir, which is in alluvium that underlies the valleys.

The ground water stored in the alluvium is of suitable chemical quality for most uses. Water from wells along the central drainage is considered excellent to good for irrigation. The quality of the water from most of the wells sampled is within the desirable limits set by the Public Health Service for drinking water.

Altar Valley is largely undeveloped, and ground water is used mainly for domestic and stock purposes and for a minor amount of irrigation. In Avra Valley some ground water was used for agricultural development as early as 1940, but it was not until about 1950 that large amounts of ground water were withdrawn. At the present time (1965), the effect of ground-water withdrawal in this area is a regional lowering of the water level. From spring 1955 to spring 1965 the average decline of the water level in Avra Valley was nearly 40 feet. In spring 1965, the depth to water was about 200 feet below the land surface at the north end of the area and about 350 to 400 feet in the center of the area where ground-water withdrawal is greatest. At the south end of the area, where only a small amount of ground water is pumped, the depth to water was more than 425 feet below the land surface at the southeast corner but was only about 175 feet near Three Points about 6 miles to the west.

Analyses of well data collected over a period of several years indicate that the transmissibility of the aquifer in Avra Valley is about 100,000 gallons per day per foot. The effects of the withdrawal of ground water from 1955 to 1965 indicate that the storage coefficient of the aquifer in the area probably is about 0.15. Use of this value for the coefficient of storage and computation of the volume of sediments available for the storage of ground water suggest that about 16.5 million acre-feet of ground water may be available from storage in Avra Valley. The historical data—water-level measurements and pumpage data—have been used to predict the status of the ground-water reservoir to 1970. The predictions are shown in the form of a depth-to-water map for the future date. The same general pattern predominates for the predicted 1970 depth to water as for spring 1965, but

data show that an average decline of the water level of about 18 feet may take place from 1965 to 1970.

INTRODUCTION

The ground-water reservoirs are currently the main source of water supplies for all uses in Arizona. The amount of surface water available is not nearly adequate to satisfy the ever-growing demand for water in the State; nearly two-thirds of the supply comes from ground water. For the past several years, the average withdrawal of ground water in the State has been about 4.5 million acre-feet per year. About 90 percent of this water is used for agriculture. Most of the ground water used is being withdrawn from storage, and the ground-water reservoirs are being depleted. Problems related to the withdrawal of ground water in large quantities include the inadequacy of the supply, erratic distribution of the available supply, competition between types of use of a single supply, and deterioration in the chemical quality of the water. Attempts to solve these and other problems that may arise must be based upon a comprehensive compilation and analysis of the hydrologic and geologic data.

Location and Extent of the Area

Avra and Altar Valleys (fig. 1), in the Basin and Range lowlands of southern Arizona, are in about the central part of Pima County. The north-trending basin, in which the valleys are situated, extends from a drainage divide about 3 miles north of the international boundary to where it joins the Santa Cruz basin about 5 miles north of the Pima-Pinal County line. Altar Valley forms the upper part of the north-trending basin, and Avra Valley forms the lower part. In the upper reaches the main drainage, which forms the axis of the valleys, is called Altar Wash; in the lower reaches it is called Brawley Wash. Altar Wash heads a few miles north of the drainage divide, flows northward, and becomes Brawley Wash at an indefinite point about 6 miles south of the Tucson-Ajo highway. There is no clear-cut dividing line between Altar and Avra Valleys (figs. 2 and 3); however, for this report, an arbitrary line perpendicular to Brawley Wash in Tps. 15 and 16 S. forms the dividing line between the two valleys. Avra Valley extends northward to the Pima-Pinal County line and is separated arbitrarily from the Santa Cruz basin by the line that extends from the north tip of the Tucson Mountains to the Pima-Pinal County line. For purposes of discussion, Avra Valley is further divided into the following

Figure 1. --Area of report.

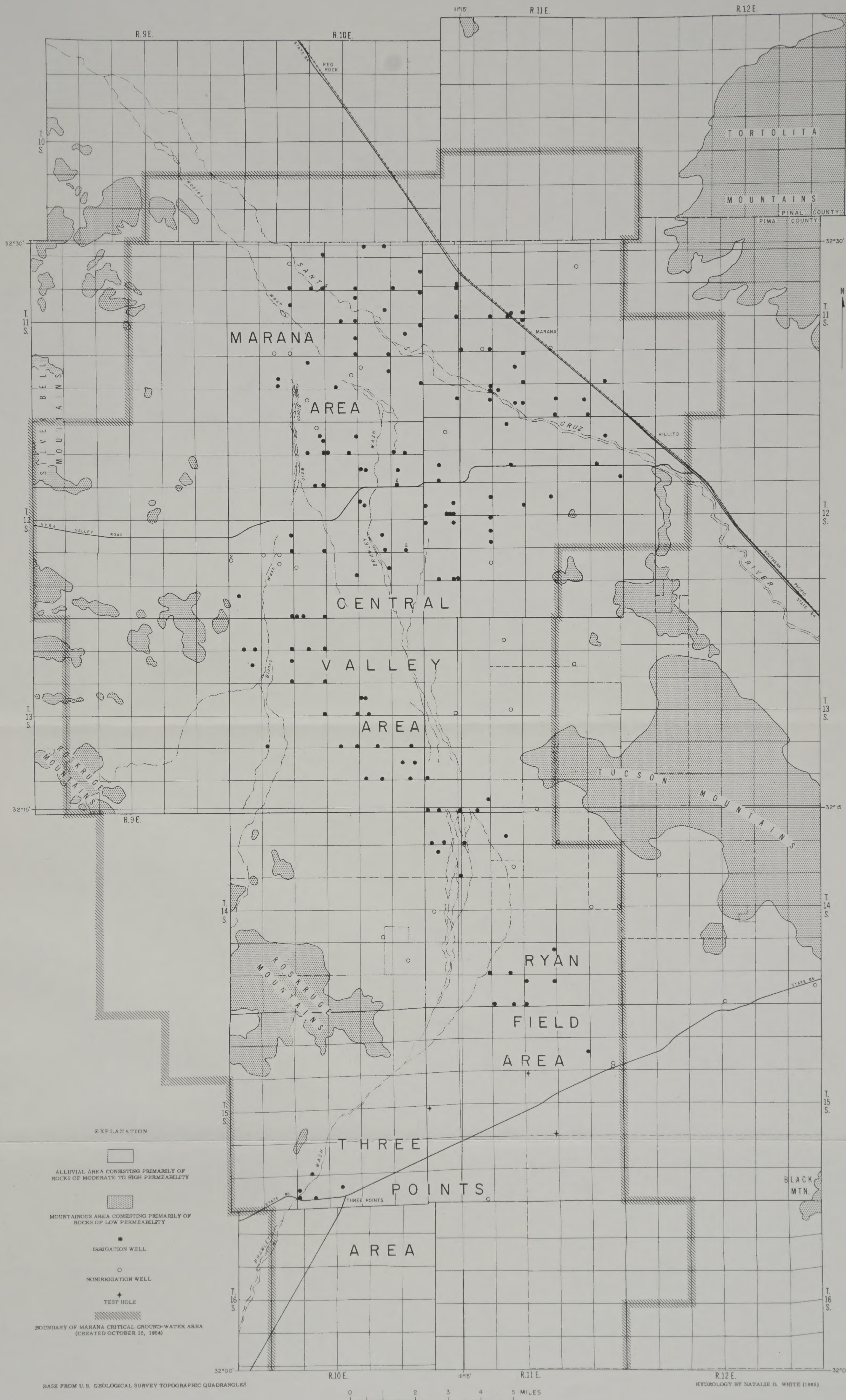


FIGURE 2.--ALLUVIAL AND MOUNTAINOUS AREAS, CRITICAL GROUND-WATER AREA BOUNDARY, LOCATION OF WELLS, AND SUBAREAS IN AVRA VALLEY.

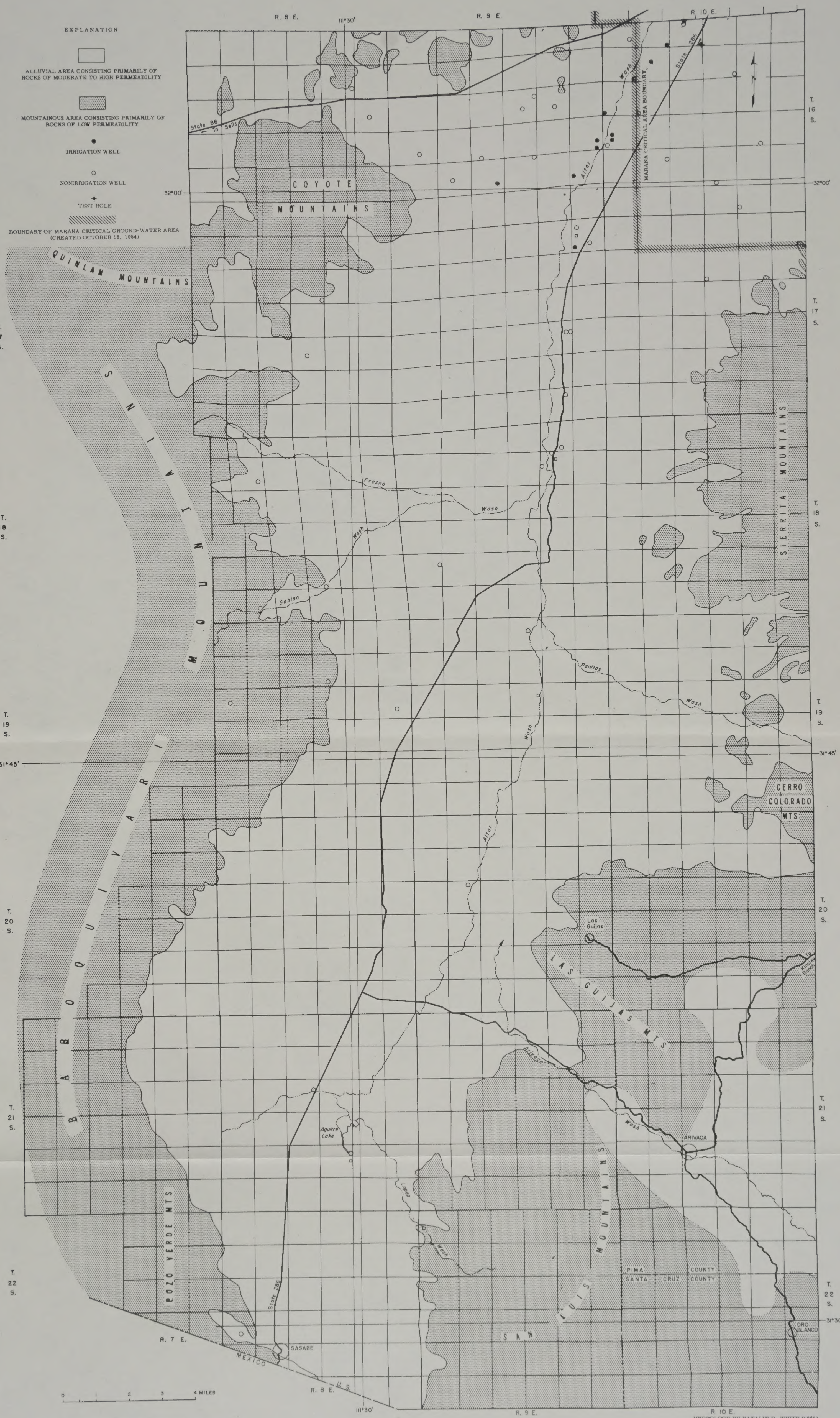


FIGURE 3.--ALLUVIAL AND MOUNTAINOUS AREAS, CRITICAL GROUND-WATER AREA BOUNDARY, AND LOCATION OF WELLS IN ALTAR VALLEY.

subareas (fig. 2): Three Points area, Ryan Field area, central valley area, and Marana area.

The basin that contains Avra and Altar Valleys is bounded on the west by the Pozo Verde, Baboquivari, Quinlan, Coyote, Roskruge, and Silver Bell Mountains; on the east it is bounded by the San Luis, Las Guijas, Cerro Colorado, and Sierrita Mountains, Black Mountain, and the Tucson Mountains, which separate it from the main drainage basin of the Santa Cruz River. The mountains that border the valleys are drained by many small washes that flow into the central part.

History of Agricultural Development

The first land developed for agriculture in the study area was in the Marana area of Avra Valley in about 1920; at that time about 6,000 acres of land was irrigated with water transported by a private irrigation company from the adjacent Cortaro area in the Santa Cruz basin. In 1937, six irrigation wells were drilled in the Marana area to augment the supply from the Cortaro area; from 1947 to 1957 nine additional wells were drilled in the area. At the same time, particularly in the years immediately following World War II, many privately owned irrigation wells were being drilled in Avra Valley. Development in Avra Valley reached a maximum in the early 1950's, and by 1954 more than 100 irrigation wells were being pumped in the area to provide water for about 30,000 acres of farmland.

In 1954 a public hearing was held at which evidence was presented that indicated that the large-scale pumping of ground water for irrigation in the Avra Valley area was sufficiently in excess of the rate of replenishment to the ground-water reservoir to cause declines in the water level. As a result of the hearing, the area was declared a critical ground-water area under the Arizona Revised Statutes (45-313C and 45-314A) on October 15, 1954. Boundaries of the critical ground-water area established at that time are shown on figure 2. Since 1954, the amount of land under cultivation has remained essentially the same; however, the amount of ground water that is pumped annually has increased, partly due to the use of double-cropping methods in the area.

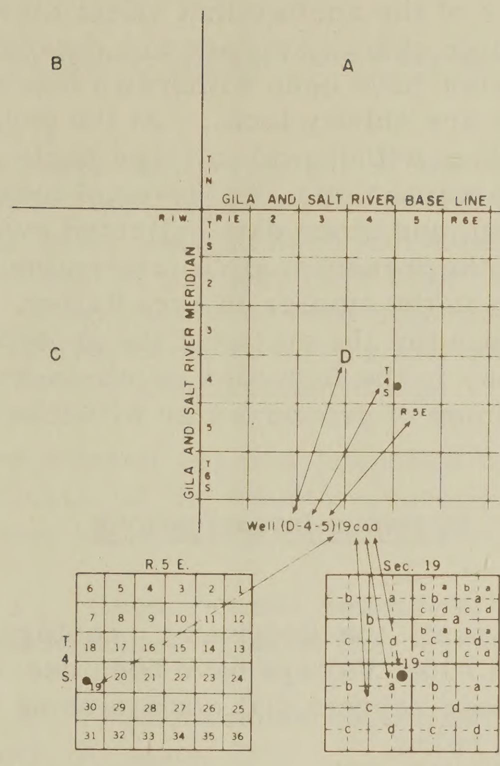
Development in Altar Valley is minimal and is confined mostly to ranching. A small amount of land was developed for irrigation just south of Three Points in the early 1950's.

Purpose and Scope of the Study

Any appraisal of the ground-water resources of an area is limited by the amount and accuracy of the data available. The data on which this study is based were collected as a part of the continuing ground-water programs of the U. S. Geological Survey and the Agricultural Engineering Department of the University of Arizona. The work done by the Survey is mainly in cooperation with the Arizona State Land Department, Obed M. Lassen, Commissioner; the work done by the Agricultural Engineering Department is in cooperation with the city of Tucson and Pima County. The programs include well inventories, periodic water-level measurements, collection of water samples for chemical analysis, and collection and cataloging of drill cuttings from new wells. These data are compiled and analyzed, and the results are summarized each year in the "Annual Report on Ground Water in Arizona"—a publication prepared by the U. S. Geological Survey and published by the Arizona State Land Department. An additional phase of the cooperative program of the Geological Survey is aimed at a systematic analysis of the current ground-water conditions in specified basins or areas. The purpose of this phase is to make better use of the data that are available; this objective is accomplished by a more comprehensive analysis of the data than can be achieved for the annual report on ground water for the entire State and by publication of this analysis in separate reports that are more detailed and timely for use by the public. This report is the third in the series of reports by the Geological Survey and is the first prepared in conjunction with the Agricultural Engineering Department of the University of Arizona.

During the fall of 1964, personnel of the U. S. Geological Survey made a complete inventory of the existing wells in Avra and Altar Valleys. In addition to the data collected by the Geological Survey, many water-level measurements and land-surface altitudes at wells and other data were available from records of the Agricultural Engineering Department of the University of Arizona. Table 2 (see appendix) shows data for many of the wells and includes the date drilled, depth of well, casing information, water-level and pumping data, and specific capacity where available. Table 3 gives selected drillers' logs of wells that are representative in the area. The locations of the wells are shown on figures 2 and 3, and all well locations in the valleys are described according to the well-numbering system used in Arizona (fig. 4).

For Altar Valley, the study describes only the general occurrence of ground water because data are insufficient to make further analyses. For Avra Valley, where data are more complete, the study describes the



The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown, well number (D-4-5)19caa designates the well as being in the NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 4 S., R. 5 E. Where there is more than one well within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes.

Figure 4.--Well-numbering system in Arizona.

general characteristics of the aquifer that affect the availability of water, and some specific aquifer characteristics are determined. Only minor amounts of ground water have been withdrawn from the aquifer in Altar Valley, and the effects are chiefly local. At the present time, however, the effect of ground-water withdrawal in large parts of Avra Valley is a regional lowering of the water table. Water-level measurements, the volume of water withdrawn, and other data collected over a period of several years have been used in the present study to determine the volume of water available from storage in the aquifer in Avra Valley. These and other data also have been used to predict the status of the ground-water reservoir to 1970. The predictions, in the form of a depth-to-water map, are based on a hypothesized regimen of ground-water withdrawal.

Previous Investigations

For the most part, the geography, geology, and ground-water resources of Avra and Altar Valleys have been described only briefly in previous reports. Those reports that contain some information regarding the area are listed below.

1925. Bryan, Kirk, The Papago country, Arizona—a geographic, geologic, and hydrologic reconnaissance with a guide to desert watering places: U. S. Geol. Survey Water-Supply Paper 499, 436 p.

1937. Andrews, D. A., Ground water in Avra-Altar Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 796-E, p. 163-180.

1952. Cushman, R. L., Lower Santa Cruz area, Pima and Pinal Counties, in Ground water in the Gila River basin and adjacent areas, Arizona—a summary, by L. C. Halpenny and others: U. S. Geol. Survey open-file report, p. 115-135.

1965. Heindl, L. A., and White, N. D., Hydrologic and drill-hole data, San Xavier Indian Reservation and vicinity, Pima County, Arizona: Arizona State Land Dept. Water-Resources Rept. 20, 48 p.

In addition to the above reports, the ground-water conditions in Avra Valley have been discussed in the "Annual Report on Ground Water in Arizona." For the last 3 years, the discussion has been given under the heading "Avra-Marana Area" in these reports; prior to that time they were discussed under the general heading "Pima County."

Acknowledgments and Personnel

During the years that personnel of the U. S. Geological Survey and the Agricultural Engineering Department of the University of Arizona have been collecting basic data in Avra and Altar Valleys, the farmers, owners, and well drillers in the area have been cooperative in furnishing useful information. Logs, pumping-test information, and other data for several deep wells drilled recently for the city of Tucson were furnished by L. C. Halpenny, Water Development Corp.

Several unpublished reports prepared by consulting geologists and engineers give data on the water resources of the valleys that have proved helpful. These reports are listed below.

1958. Turner, S. F., Ground-water resources available for use on the Cortaro and Marana Farms areas, Pima County, Arizona.

1959. Turner, S. F., Water resources available to the city of Tucson, Pima County, Arizona.

1965. Halpenny, L. C., and Greene, D. K., Appraisal of 1965 test drilling in Avra Valley, city of Tucson.

The authors wish to acknowledge the assistance of the people, both field and office personnel, employed in the respective agencies. R. J. Shaw has collected most of the field data for the ground-water program of the Agricultural Engineering Department, University of Arizona, for many years. His personal knowledge of the valleys has been helpful. In the U. S. Geological Survey, field personnel who have collected data include E. K. Morse, R. L. Thompson, W. B. Garrett, and Dallas Childers, Jr. The illustrations were drafted by G. S. Smith, F. R. Rascop, and J. R. Dusard, Jr.; the cover illustration was prepared by Mr. Dusard. Those who assisted with the computations include Jane V. Burton and Toni S. Kuehner. The manuscript was prepared for reproduction by Carol L. Hicks, Helen S. Price, and Ruth L. Blubaugh.

THE GEOHYDROLOGIC SYSTEM

The availability of water in an area and the results of its development and use depend on the geohydrologic system. The climate, terrane, and geology are factors that control the entrance of water into an area and

the manner in which it moves through and leaves the area. Precipitation, the ultimate source of the water, is a function of the climate; the occurrence of surface water or ground water is determined primarily by the terrane and the geology.

The geohydrologic system of Avra and Altar Valleys is typical of other valleys in the Basin and Range lowlands province of southern Arizona. In Avra Valley the flat-lying valley floor, which is surrounded and in places pierced by steeply rising mountains, is underlain by coarse materials that allow the storage of large volumes of water; the valley floor in Altar Valley is somewhat narrower and provides less storage of ground water. Precipitation in the area is slight and variable and often occurs as intense rainfall of short duration. The streams in the area are intermittent and flow only during and immediately following rainstorms. The valleys are drained principally by Altar and Brawley Washes.

Climate

The climate of Avra and Altar Valleys is arid and is characterized by low precipitation and high summer temperatures, which, combined with the low humidity, cause high rates of evaporation. These arid conditions result in the evaporation of a large part of the precipitation before it can be used beneficially by crops or be recharged to the ground-water reservoir. Data from several climatological stations in and near the valleys indicate a wide range in precipitation from place to place and from year to year. The average annual precipitation probably is less than 10 inches at the lower altitudes in the central parts of the valleys, but it may be as much as 17 inches on some of the higher slopes (table 1); precipitation rates also vary greatly from month to month during the year.

In general, local and torrential rainstorms occur in the summer; winter storms are generally regional, gentle, and of longer duration. The pattern of runoff corresponds to that of the rainstorms. Runoff following the summer storms usually has a high peak but subsides quickly; winter and spring flows have lower peaks but last longer. A part of the runoff that emerges from the mountain areas probably infiltrates to the ground-water reservoir through the coarse materials at the base of the mountains and along the stream channels. However, because of the arid climate, much of the runoff evaporates quickly.

Evaporation is a function of temperature, wind, humidity, and barometric pressure and is a nearly continuous process. The U. S. Weather

Table 1. --Climatic data for stations in and near Avra and Altar Valleys

[Data from Green and Sellers (1964), Smith (1956), and U. S. Weather Bureau (annual)]

Station	Altitude (feet above mean sea level)	Item[1]	Period of record[2]	Average length of record (years)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Red Rock, 6 SW., 32°30'	1,860	Precipitation, inches	1893-1957	33	0.77	0.57	0.84	0.30	0.13	0.25	1.57	1.63	1.15	0.47	0.86	1.03	9.57
		Temperature, °F	1893-1957	8	49.2	55.7	58.8	65.5	72.1	82.8	90.0	87.7	83.6	71.5	59.6	51.3	69.0
Silver Bell, 32°23'	2,740	Precipitation, inches	1906-57	18	1.27	.91	.80	.18	.28	.24	3.03	2.34	1.19	.78	.78	1.04	12.84
		Temperature, °F	1906-57	15	53.2	57.1	61.8	67.5	74.5	85.4	85.8	84.4	82.8	72.4	61.6	54.0	70.0
Anvil Ranch, 31°59'	2,750	Precipitation, inches	1943-64	22	.68	.54	.79	.35	.16	.16	2.48	2.30	1.48	.76	.45	.63	10.78
		Temperature, °F	1944-64	21	48.9	51.2	56.1	64.6	71.6	81.9	85.6	82.8	79.2	69.8	56.3	50.2	66.5
Sasabe, 7 NW., 31°35'	3,825	Precipitation, inches	1951-64	14	1.60	.72	1.27	.43	.08	.33	3.92	3.86	1.83	1.25	.93	1.04	17.32
Arivaca, 1 E., 31°35'	3,675	Precipitation, inches	1956-64	9	1.04	.55	.82	.20	.03	.48	4.39	3.75	1.47	1.35	.86	1.01	15.94
Average evaporation, in inches, at Tucson (University of Arizona) 1928-54					2.42	3.34	5.91	8.62	11.37	12.86	11.75	9.82	8.48	6.15	3.59	1.56	85.15

1/ Mean for period of record indicated.

2/ Period of years during which records were reported; not necessarily continuous.

Bureau measures evaporation in a standard 4-foot pan at several stations in Arizona. Although such measurements do not represent the evapotranspiration potential from land areas, they are an index to a characteristic of the climate that acts to limit the quantity of water available for beneficial use. An evaporation station is maintained at the University of Arizona in Tucson (table 1), and evaporation in the Avra Valley part of the study area probably is about the same as at the Tucson station; because of the higher altitudes, it may be somewhat different in Altar Valley.

In arid climates the ability of the atmosphere to cause water to evaporate and transpire is much greater than the water available from precipitation. Thornthwaite (1948) has devised a method for computing the potential evapotranspiration based on temperature and the latitude of the station. For Avra Valley, data for three stations along the valley were averaged and used to compute average monthly figures for potential evapotranspiration. These potential evapotranspiration rates are shown graphically in figure 5 and are compared with the monthly precipitation. Precipitation is in excess of potential evapotranspiration only in January and December, and even then the excess is small compared to the amount of potential evapotranspiration in excess of precipitation during the rest of the year. Thus, table 1 and figure 5 clearly indicate the small amount of water available for recharge to the ground-water reservoir or for beneficial use by crops in Avra Valley.

Geologic Setting

The geologic setting of Avra and Altar Valleys is typical of that in many valleys in the Basin and Range lowlands province. Dense, impermeable bedrock forms the mountains that bound the valley floors; pediment areas, in which the bedrock is at a shallow depth, extend valleyward for varying distances from the base of the mountains; and the central part of the valley area is underlain by great thicknesses of alluvial sediments.

Avra and Altar Valleys are bounded on the west by the Pozo Verde, Baboquivari, Quinlan, Coyote, Roskruge, and Silver Bell Mountains and on the east by the San Luis, Las Guijas, Cerro Colorado, Sierrita, and Tucson Mountains, and Black Mountain (figs. 2 and 3). Along the west side of the valleys the rocks in the Pozo Verde and Quinlan Mountains and on the lower eastern slopes of the Baboquivari and Coyote Mountains are mainly granite of Tertiary age. The south end and the higher slopes of the Baboquivari Mountains are composed mainly of schist that is Tertiary in age. Gneiss predominates on the peaks of the Coyote Mountains. The

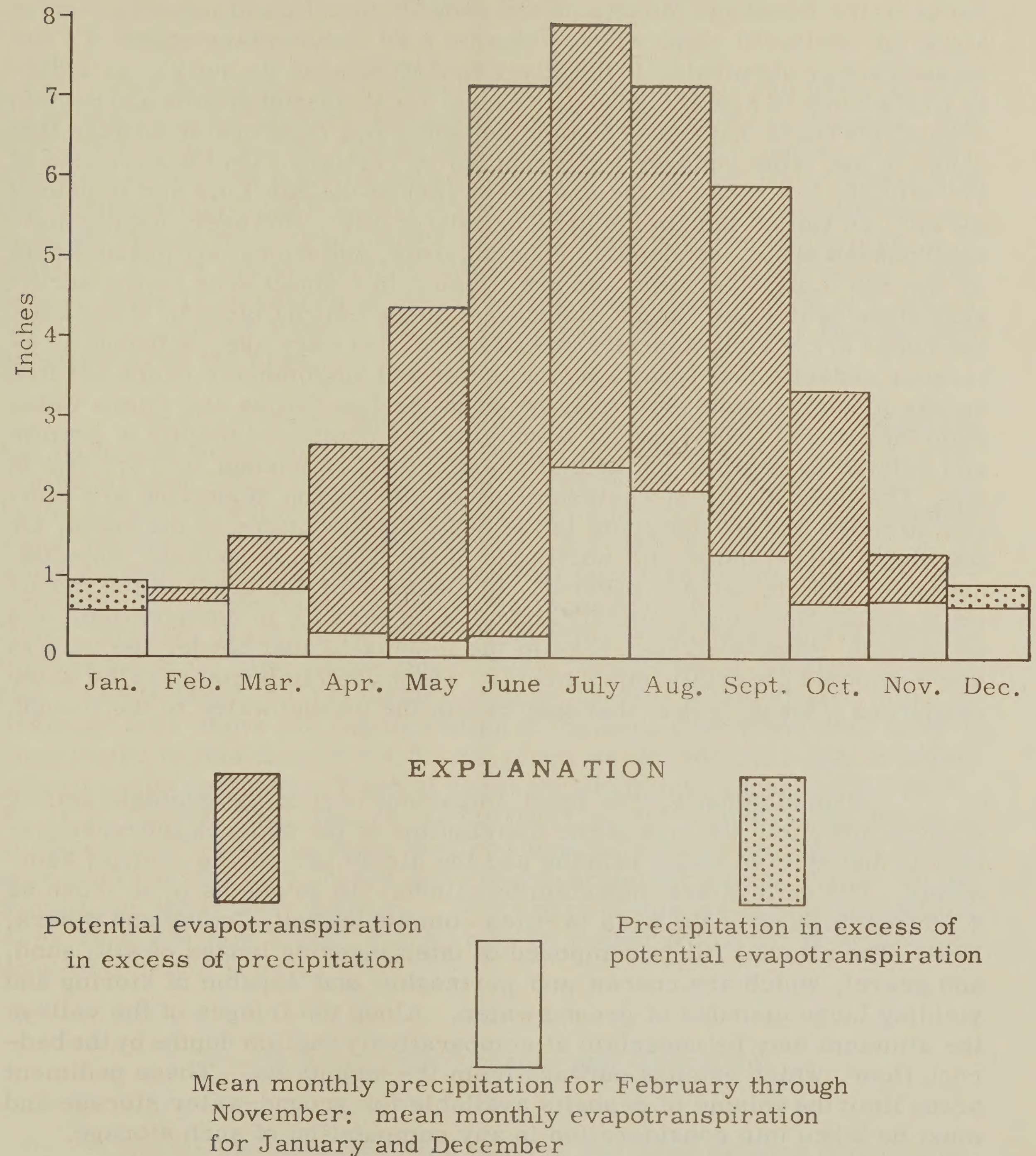


Figure 5. --Precipitation and potential evapotranspiration, Avra Valley.

rocks in the Roskruge Mountains are mostly rhyolite and andesite, except along the northeast slope where volcanic and sedimentary rocks of Cretaceous age predominate. In the Silver Bell Mountains the rocks are chiefly Cretaceous in age and younger, except for an area of granite and related crystalline rocks that are Precambrian and a few outcrops of diabase that range in age from younger Precambrian to Tertiary. On the east side of the valleys, the rocks in the southwest part of the San Luis and in nearly all the Las Guijas Mountains are Tertiary granite. However, locally metamorphosed shale, sandstone, conglomerate, and limestone predominate in the San Luis Mountains and are present in a small area on the northeast slope of the Las Guijas Mountains. In the Cerro Colorado Mountains, the rocks are mainly andesite and basalt of Tertiary age, although Cretaceous andesite that locally includes tuff and agglomerate crops out in a series of comparatively low hills between the Las Guijas and Cerro Colorado Mountains. The Sierrita Mountains are composed mainly of granite and related crystalline rocks that range from Cretaceous to Tertiary in age. The rocks along the western slope of the Tucson Mountains are similar to those that predominate in the San Luis Mountains to the south. On the higher slope and at the north end of the Tucson Mountains, rhyolite, andesite, and granite are present. In places near the crest of the mountains, dikes and plugs, mainly andesitic to basaltic in composition, are prominent. Nearly all the rocks in the mountains that border the valleys are dense and generally impermeable. Their chief importance to the water resources of the valleys is that they retain the ground water in the trough.

Hydrologically, the most important part of the geologic setting of Avra and Altar Valleys is the distribution of the bedrock and other materials that are not water bearing and the highly permeable alluvial sediments. The valleys are underlain by alluvial fill to depths of as much as 2,000 feet in parts of the area (written communication, Cooley and others, 1964). The alluvial fill is composed of interfingering lenses of silt, sand, and gravel, which are coarse and permeable and capable of storing and yielding large amounts of ground water. Along the fringes of the valleys the alluvium may be underlain at comparatively shallow depths by the bedrock floor, which extends outward from the mountains. These pediment areas limit the volume of deposits available for ground-water storage and must be taken into consideration in any computation of such storage.

The logs of several wells drilled recently for the city of Tucson show a red mudstone, probably of Tertiary age, at depths ranging from about 1,500 to 2,000 feet. This material is firmly cemented and probably would yield only small amounts of water to wells.

Surface Water

Surface water in Avra and Altar Valleys is limited to the flow in Altar and Brawley Washes, the main drainage channels for the area, and their tributaries. All the flow is intermittent, and flow from the mountain washes reaches the main drainage only during times of heavy rainfall and the resulting high-peak flows; however, some of the larger mountain washes, such as Blanco Wash, may carry large amounts of water during high-peak flows. There are no surface-water gaging stations in the valley, and, hence, there is no record of the amount of water that enters and leaves the area as surface flow. Only a small part of the surface flow is used beneficially in the area.

The study area, especially Avra Valley, is subject to extensive and damaging floods that occur as a result of torrential rainstorms on the drainage basin. More important to the overall water resources of the area is the amount of water that might be available for recharge to the ground-water reservoir from these floodflows. A report by Lewis (1963, p. 1) gives a detailed description of a flood that occurred in Avra Valley in September 1962. According to Lewis: "The floods spread over the Santa Cruz River, Brawley Wash, Santa Rosa Wash, Sells Wash, and some of the tributaries but at no time did the entire basin receive great amounts of rainfall." Lewis (1963, p. 11) further states: "Nearly 5,000 square miles of drainage area above the gaging station on the Santa Cruz River near Laveen contributed to this flood * * *." As much as 40,000 acre-feet of water passed a point on Brawley Wash at about the southwest corner of T. 13 S., R. 11 E. (Lewis, 1963, fig. 9). Lewis (1963, p. 20) indicates that the total surface runoff resulting from the flood must have been in excess of 125,000 acre-feet but that only 17,400 acre-feet reached the gaging station on the Santa Cruz River near Laveen. What part of this water was lost within Avra Valley or how much, if any, may be recharged to the ground-water reservoir is not known.

Ground Water—Occurrence and Movement

Nearly all the water used in Avra and Altar Valleys comes from the ground-water reservoir. The valley floor is underlain by permeable alluvium, which is capable of storing and yielding large amounts of ground water. For the most part, the water in the subsurface is the result of an accumulation over many thousands of years, although some water is recharged annually.

The alluvium consists of permeable lenses of sand and gravel interbedded with clay and silt. The alluvial fill is present to depths as great as 2,000 feet along the central parts of the valleys; however, along the mountain fronts, the thickness is considerably less (written communication, Cooley and others, 1964). For the most part, the water-bearing materials are interconnected throughout the area, at least to a depth of 700 feet, and a single water-table aquifer is present. However, there is some evidence from logs of recently drilled wells that water below a depth of about 1,100 feet is confined below less permeable materials and may rise above the regional water table in parts of the area (oral communication, E. S. Davidson, 1965). At the present time (1965), there are only a few wells that have been drilled to depths of more than about 700 feet, and, therefore, the extent of this confined aquifer cannot be determined.

The direction and rate of movement of ground water in an alluvial basin, such as Avra and Altar Valleys, is a function of several factors. Prior to the development of ground water, the aquifer was in approximate hydrologic balance; that is, on a long-term basis the amount of water moving into the basin was approximately equal to the amount moving out of the basin, although short-term inflow and outflow rates might have been far out of balance. Movement of ground water was from areas of higher to areas of lower head in the aquifer; flow lines drawn at right angles to the contours of equal head, based on water levels measured in the undisturbed state, show the direction of movement. The water-level contours for Avra Valley (fig. 6) are based on measurements of the water level made in 1940 prior to any significant amount of ground-water development in that area. For Altar Valley, data are insufficient to prepare contours for this early period; however, as there has been very little development in this area, the contours for 1965 (fig. 7) probably represent essentially undisturbed conditions. The slope of the water surface, as indicated by the contours (figs. 6 and 7), was generally northeastward and then northward, and it conformed to the general slope of the land surface and the trend of the main drainage. Ground water moved from the mountain areas toward the centers of the valleys, and some ground water moved into Avra Valley near Three Points from Altar Valley. A nearly similar amount of ground water moved out of Avra Valley at the north end into the lower Santa Cruz basin. When man imposes new stresses on the ground-water system in the form of new discharge points, such as wells, the response of the system is a change in the flow pattern. Extensive development of the ground-water resources of Avra Valley began in about 1950; since that time many wells have been drilled, and large amounts of ground water are withdrawn each year. At the present time, about 30,000 acres of land is under cultivation, and the annual withdrawal of ground water is about 115,000 acre-feet. The contours of the water level (fig. 8) in Avra Valley, based on

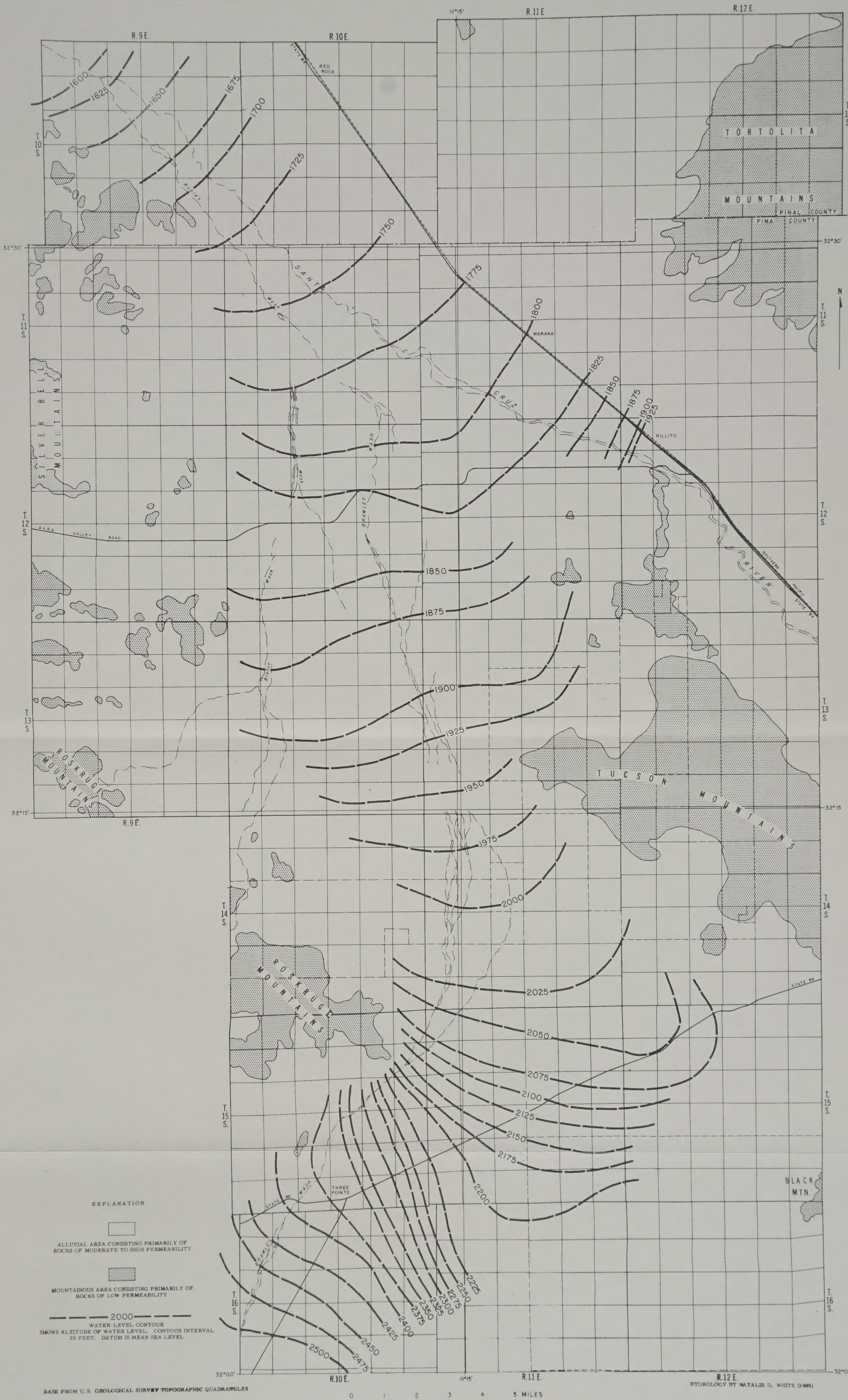


FIGURE 6.--WATER-LEVEL CONTOURS, 1940, IN AVRA VALLEY.

FIGURE 7.--WATER-LEVEL CONTOURS, SPRING 1965, IN ALTAR VALLEY.

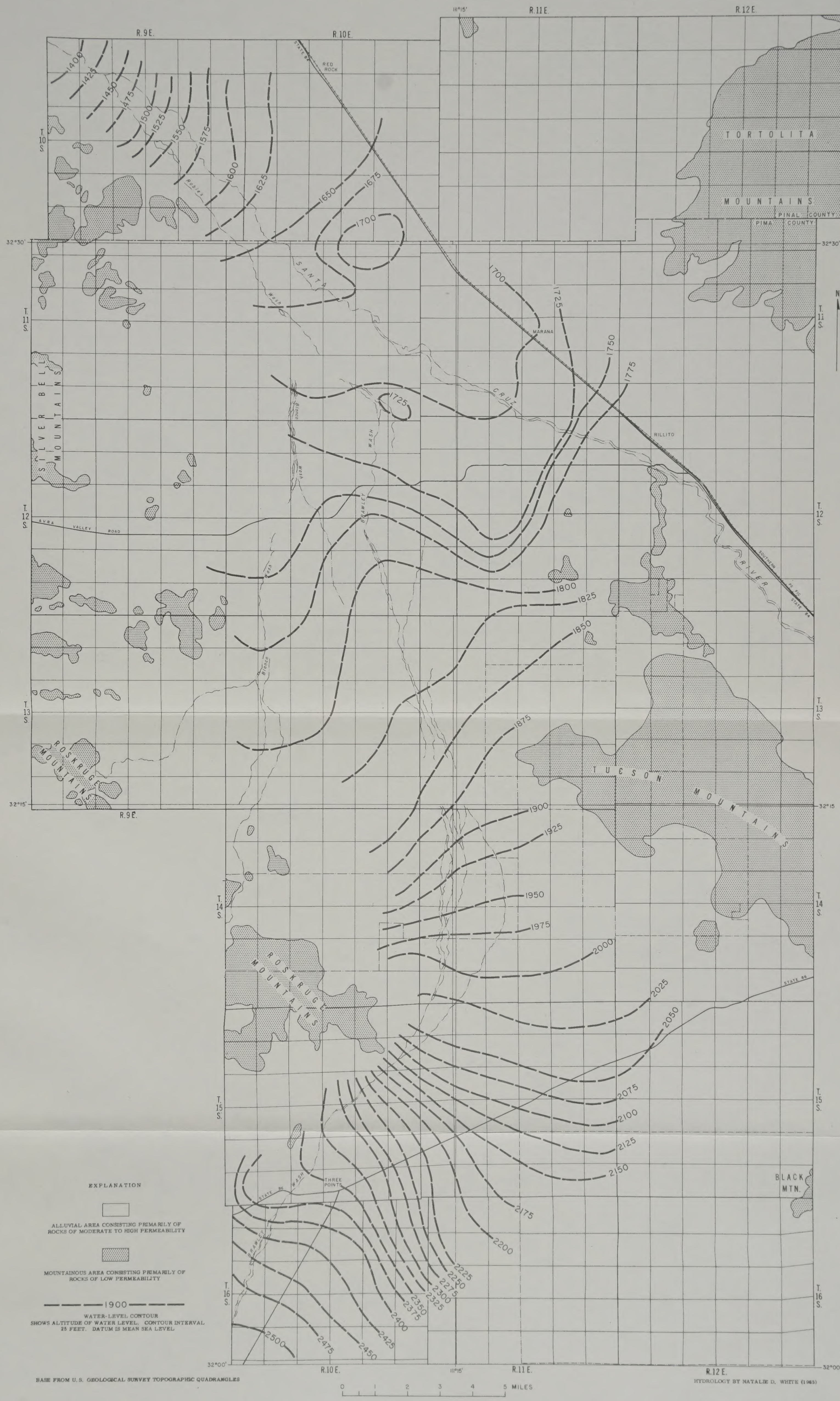


FIGURE 8.--WATER-LEVEL CONTOURS, SPRING 1965, IN AVRA VALLEY.

measurements made in spring 1965, show the changes in the flow pattern as a result of the withdrawal of ground water. For the most part, the changes are minor and are apparent mainly in the central part of the valley where the largest amount of development has taken place. The contours show a slight steepening in the gradient of the water surface into the valley at the south end near Three Points and a slightly greater steepening at the north end of the valley where ground water moves into the highly developed Eloy area of the lower Santa Cruz basin. However, the difference in gradients at the south and north ends of the valley may not be significant, and, for practical purposes, the natural inflow and outflow rates probably are almost the same as in the earlier period. Any small difference would be unimportant in relation to the large amount of ground water withdrawn by pumping.

Similarly, the amount of recharge to the ground-water reservoir probably is negligible in relation to ground-water withdrawal by pumping. There is some evidence of recharge to the ground-water reservoir from floodflows in the main drainage channels. Cumulative net changes in water level indicate a slight reduction in the decline from 1962 through 1964 that might be the result of recharge from floods. Data are insufficient to determine the amount of this recharge; however, it is probably small because of the great depth to the water table and the extremely slow rate of travel of ground water in the subsurface material.

Chemical Quality of the Ground Water

The chemical quality of the ground water in an area, particularly in relation to its chief uses, is important to the overall evaluation of the water resources. The suitability of ground water for various uses can be determined from chemical analysis of water samples taken from wells in the study area. In Altar Valley ground water is used mainly for stock and domestic purposes, and only a minor amount is used for irrigation; in Avra Valley the chief use of ground water is for the irrigation of crops.

Water applied for irrigation generally is evaporated from the soil or transpired from the growing plants; because the dissolved mineral matter in the water cannot evaporate or transpire, it accumulates in the soil. It is important, therefore, that the water used for irrigation be sufficiently low in dissolved-solids content to avoid excessive accumulation. This is particularly true in arid areas, such as Avra and Altar Valleys, where surplus water is not available to flush out the accumulated salts. No rigid standards can be set for the amount of dissolved minerals permissible in

irrigation water; however, Wilcox (1948, p. 26) has classified water for such use on the basis of percent sodium and specific conductance.

Tables 4 and 5 (see appendix) contain complete or partial chemical analyses of the water from selected wells in Avra and Altar Valleys. The total dissolved solids, in parts per million, is about 0.6 of the specific conductance. The specific conductance of the water from wells along the central drainage of the valleys generally ranges from slightly less than 350 (micromhos at 25°C) to nearly 600, which is within the range of "excellent to good" for irrigation water as classified by Wilcox (1948). Water from a well near the Tucson Mountains had a specific conductance of 750, and water from a well near the Roskruge Mountains had a specific conductance of 1,080. The water from these wells probably is affected by the older sedimentary rocks that crop out in the mountains. For the most part, the water sampled is from wells less than 600 feet deep. However, water from a deep well (more than 1,800 feet) drilled recently for the city of Tucson in the upper part of Avra Valley near Three Points had a specific conductance similar to that of water from the shallower wells.

The U.S. Public Health Service (1962, p. 7) has set standards for the chemical characteristics of water to be used for drinking purposes. In general, drinking water should contain no more than 500 mg per l (milligrams per liter) of dissolved solids. The water from all the wells sampled in Avra and Altar Valleys is within the desirable limits set by the U.S. Public Health Service. An important constituent of drinking water that has received a large amount of attention in recent years is fluoride. Excessive amounts of fluoride in drinking water that is consumed by young children cause mottling of the enamel of the permanent teeth. The recommended control limits for fluoride concentrations differ, according to the annual average of maximum daily air temperatures. For Avra and Altar Valleys the upper limit is about 0.8 mg per l, and the optimum value is 0.7 mg per l (U.S. Public Health Service, 1962, p. 8). Tables 4 and 5 show that only a few water samples had a fluoride content sufficiently in excess of these amounts to cause concern. However, water from a deep well drilled recently to a depth of more than 1,800 feet near Three Points had a fluoride content of more than 4 ppm (parts per million)—analysis not shown in tables. Data are insufficient to determine the reason for the apparent increase in fluoride content with depth at the present time.

HYDROLOGIC CHARACTERISTICS OF THE AQUIFER

This section of the report will apply only to the Avra Valley part

of the study area. In Altar Valley, the withdrawal of ground water is minor, water-level changes are local, and data are insufficient to determine the hydrologic characteristics of the aquifer.

In Avra Valley, ground water currently is being withdrawn from the aquifer in excess of the rate of replenishment. The results of this withdrawal of ground water from storage depend on the hydrologic characteristics of the aquifer that control the storage capacity, the total amount of water available for withdrawal, and the rate of transmission of water. A determination of these characteristics makes it possible to understand the physics of the ground-water system and helps to evaluate the ground-water resources of an area in relation to the development of these resources. The rate at which an aquifer will yield water to wells is a function of the transmissibility of the aquifer. This and other terms that describe the hydrologic characteristics of the aquifer have been defined by Ferris and others (1962). The coefficient of transmissibility is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. The volume of water that the aquifer releases from or takes into storage per unit surface area per unit change in head normal to that surface is called the coefficient of storage. The ratio of the storage coefficient to the transmissibility of the aquifer determines the rate at which the cone of depression will spread around a pumping well. From the data available for Avra Valley, estimates of the transmissibility and storage coefficients have been made, and the estimates probably are in the correct order of magnitude. The methods used to determine these characteristics and the results obtained are described below.

Transmissibility Determined from Well-Data Analysis

In this study the coefficient of transmissibility was estimated from the specific capacity of individual wells by a method described by Thomasson and others (1960, p. 222). The specific capacity of a well is the relation of yield to drawdown—that is, its yield in gallons per minute per foot of drawdown of the water level caused by pumping. The method consists of multiplying the specific capacity by an empirical factor (determined experimentally) to obtain an approximate value for the coefficient of transmissibility. The specific capacity of a well is a function not only of the hydrologic characteristics of the aquifer but also of the construction of the well, particularly the condition of the perforations in the casing, the distribution of the perforations within the saturated zone, and the depth that the well penetrates the saturated zone. Therefore, the value

of transmissibility estimated from specific capacity will be affected by these factors. For the most part, transmissibility estimated from specific capacity will tend to be lower than the true transmissibility of the aquifer. However, because most of the data for specific capacities of wells used in this study were from tests made at the time of completion of the well, when perforations in the casing were open, it is probable that the values obtained for transmissibility are very near the true values for the part of the aquifer penetrated by the wells.

Transmissibility of the aquifer in Avra Valley, estimated from the specific capacity of wells, ranges from about 20,000 to more than 200,000 gpd (gallons per day) per foot (table 2). In the Three Points area the average transmissibility is about 60,000 gpd per foot, in the Ryan Field and central valley areas it is about 80,000 gpd per foot, and in the Marana area it is about 150,000 gpd per foot. The overall average transmissibility for the valley is about 100,000 gpd per foot.

The values computed above are a measure of the transmissibility for only the upper 500 to 700 feet of material, because the data on which the estimates are based are from wells that are only 500 to 700 feet deep. Below a depth of about 700 feet the materials may be somewhat finer grained and yield water less readily. Data are insufficient to ascertain the transmissibility of the aquifer below a depth of 700 feet.

Transmissibility Determined from Aquifer Tests

The hydrologic characteristics of aquifers can be determined by means of aquifer tests in which the effect of pumping a well at a known rate is measured in the pumped well and in nearby observation wells. The data obtained during the tests are analyzed by means of mathematical formulas that relate the hydrologic properties of the aquifer to the change in water levels in and near a pumped well. The particular formula to be used depends on the data available. Similarly, whether all or only part of the hydrologic characteristics of the aquifer can be determined depends on the data obtained from the tests. For example, with data from only the pumped well, the transmissibility of the aquifer can be computed but not the storage coefficient. The different formulas that have been derived are described in several publications (Ferris and others, 1962; Brown, 1953) and will not be discussed further here.

To some extent, values of the hydrologic characteristics determined from aquifer tests must be considered as point data and not as

regional characteristics for a widespread nonhomogeneous aquifer system. In this respect, then, the data are similar to those obtained from analysis of well data; if a sufficient number of tests are available well distributed over an area, then the values derived may be indicative of the entire aquifer system.

Data from six aquifer tests made in Avra Valley from 1942 to 1965 were available for analysis. The tests provided data only from the pumped well, and, thus, only the transmissibility could be determined. Therefore, these tests do not represent a complete analysis of the aquifer characteristics but serve only as indicators of the magnitude of the characteristics and show the areal variance over the valley. Values of transmissibility obtained from the tests ranged from about 40,000 to 130,000 gpd per foot. The location of the pumped well, date of the test, and value of transmissibility obtained are tabulated below:

Well location	Date of test	Computed transmissibility (gpd per foot)
(D-12-10)14	10/42	70,000
(D-15-10)33	6/58	40,000
(D-15-11)11	5/58	130,000
(D-16-9)28	11/57	46,000
(D-16-10)4	5/65	77,000
(D-16-10)8	5/65	44,000

In general, the values obtained from the tests agree with those obtained by the analysis of well data described in the foregoing section.

Storage Coefficient Determined from Analysis of the Effects of Ground-Water Withdrawal

The coefficient of storage of the aquifer in Avra Valley has been computed on the basis of the relation between the amount of ground water withdrawn and the resultant dewatering of the aquifer. When a well is being pumped, water is removed from the aquifer, and the water level in the aquifer surrounding the well is lowered, which causes water to move toward the well. The lowering of the water surface near a well is described as the cone of depression or cone of influence of the well; the amount of lowering decreases with distance and increases with time. As the cones from many wells in an area begin to overlap, a regional cone develops that

eventually may encompass the entire valley. The depth and spread of this cone are dependent on the rate of withdrawal of water, the length of time of the withdrawal, and the transmission and storage characteristics of the aquifer. Specifically, the volume of the cone is directly proportional to the amount of water withdrawn from the aquifer and inversely proportional to the storage coefficient of the aquifer. The change in head—change in water level—multiplied by the area of aquifer surface over which it is effective determines the volume of the cone. The volume of the cone developed during a specified period of time due to the pumping of a given amount of water is equivalent to the volume of sediments dewatered during that time.

Assuming that natural inflow is of the same order of magnitude as natural outflow, the amount of ground water pumped (acre-feet) divided by the volume of sediments dewatered (acre-feet) determines the coefficient of storage (nondimensional). If there is a difference between inflow and outflow, then the storage coefficient of the aquifer determined in this manner will differ slightly from the true storage coefficient of the aquifer. It is probable that in Avra Valley the pumping of ground water has not, as yet, greatly changed the ratio of inflow to outflow, and the storage coefficient computed by this method is very nearly the true storage coefficient of the aquifer.

A map was prepared for Avra Valley showing contours of the change in ground-water level from spring 1955 to spring 1965 (fig. 9). The map shows that the amount of water-level decline during that period ranged from about 10 feet at the upper end of the valley to as much as 60 feet in the areas of greatest ground-water withdrawal. The volume of sediments dewatered by the withdrawal of ground water during that period was determined by planimetering the surface area along successive contours and multiplying this area by the amount of change represented by the contours.

Further evidence of the correlation between ground-water withdrawal and dewatering is illustrated in figure 10, which shows the cumulative change in water level and annual pumpage in Avra Valley from 1940 through 1964. The change in water level is based on measurements made in several hundred wells each year. Data from figure 10 agree with those from the map showing contours of the change in water level from spring 1955 to spring 1965. A correlation between the amount of ground water pumped annually and the trend of the cumulative decline in water levels may be seen in figure 10. For example, the decided increase in pumpage in 1951 is reflected by an increase in the slope of the line showing the cumulative change in water level.

FIGURE 9.--CHANGE IN GROUND-WATER LEVELS FROM SPRING 1955 TO SPRING 1965 IN AVRA VALLEY.

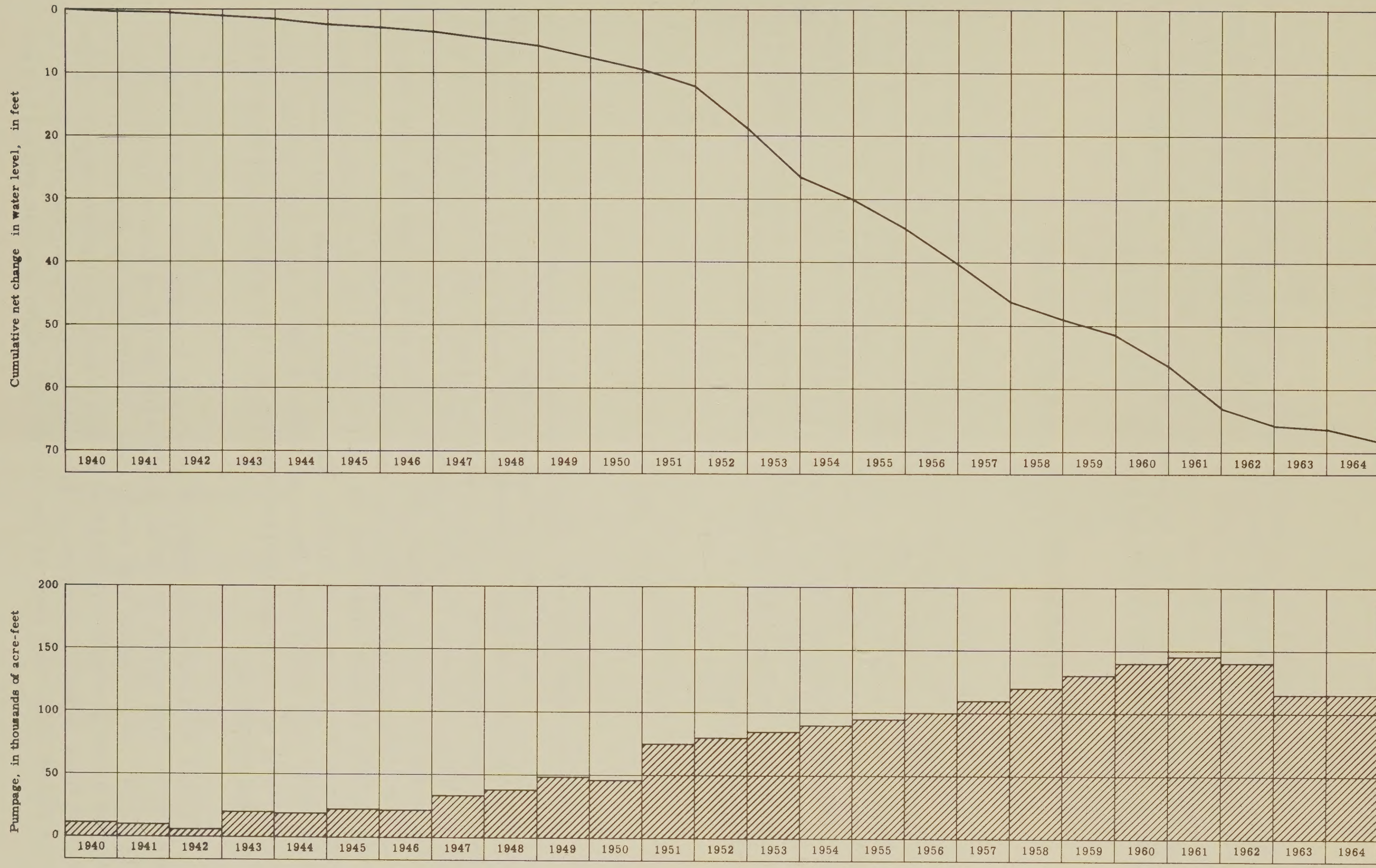


Figure 10.--Cumulative net change in water level and total annual pumpage in Avra Valley.

From spring 1955 to spring 1965, about 1.2 million acre-feet of ground water was withdrawn from the aquifer in Avra Valley, which resulted in the dewatering of about 7.3 million acre-feet of sediments (fig. 9). Thus, the storage coefficient computed from these data is about 0.16. This value probably should be adjusted to about 0.15 to account for any small amount of natural inflow in excess of natural outflow.

AVAILABILITY OF GROUND WATER

Previous sections of this report have shown that the rate of recharge to the aquifer in Avra Valley is small compared to the amount of ground water pumped each year. Thus, it is evident that most of the water pumped in the area must be withdrawn from storage—that is, ground water that has accumulated in the basin over a long period of time. A determination of the amount of water available and the effect of continued withdrawal from storage is therefore important to the proper management of the water resources of this valley. For Altar Valley, data are insufficient to make these determinations.

Water from Storage

The storage capacity of an aquifer is defined as the volume of space available to contain water—that is, the total volume of saturated sediments multiplied by their porosity. The porosity of a rock or soil is its property of containing interstices (Meinzer, 1923, p. 19) and is expressed as the percentage of the aggregate volume of the interstices to the total volume of the rock. However, because a large part of this stored water will be held in the aquifer by molecular attraction or other forces of retention, the amount that can be extracted from the aquifer is much less than the total storage capacity. The volume of water that is theoretically available for man's use from an aquifer is a function of the total storage capacity of the saturated sediments and the coefficient of storage of the aquifer material.

Figure 11 shows contours of the depth to water in Avra Valley as of spring 1965. The depth to water was about 200 feet below land surface at the north end of the area and about 350 to 400 feet in the center of the area, where ground-water withdrawal is greatest. At the south end of the area, where only a small amount of ground water is pumped, the depth to water was more than 425 feet at the southeast edge but was only 175 feet

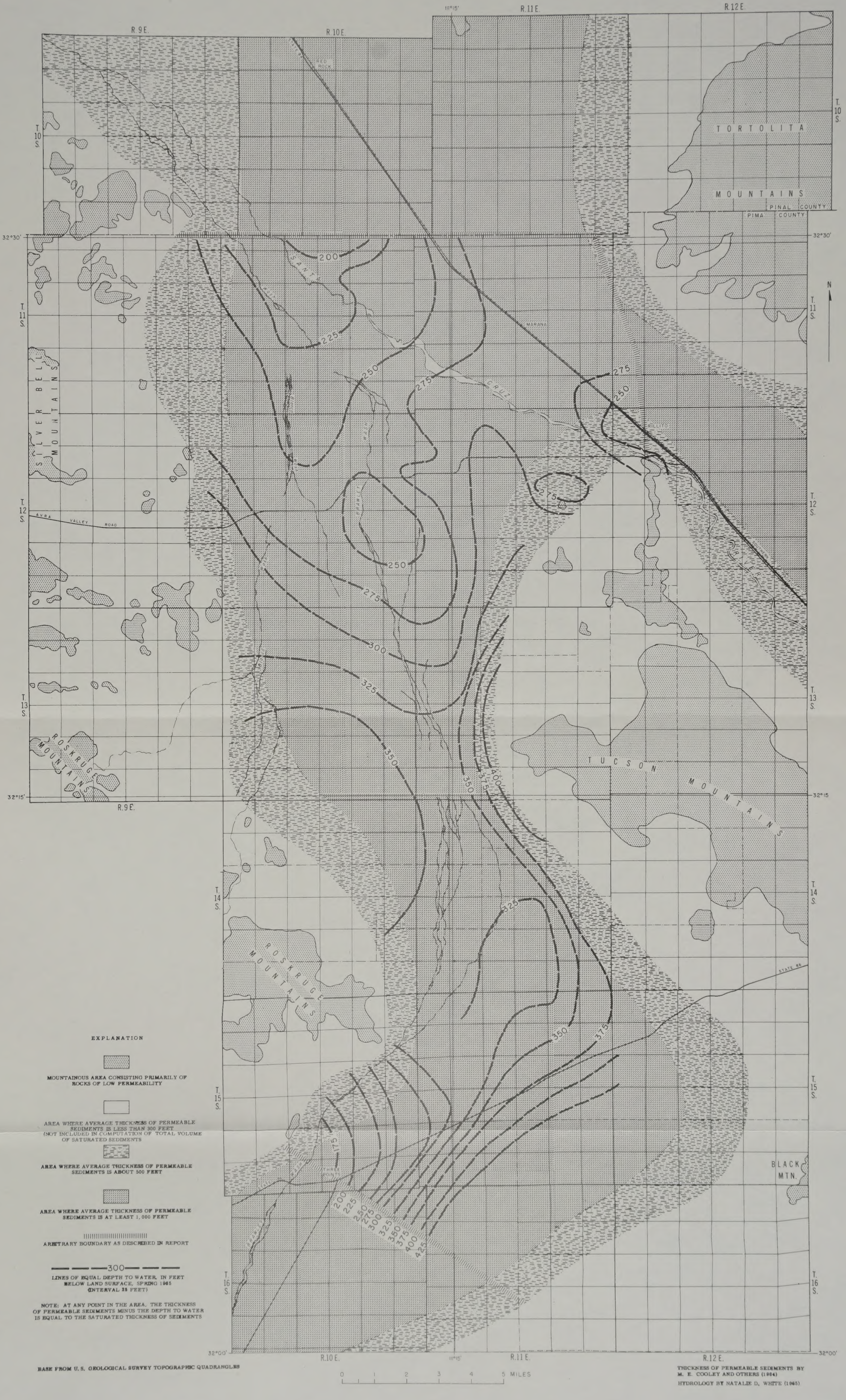


FIGURE 11.--THICKNESS OF PERMEABLE SEDIMENTS AND DEPTH TO WATER, SPRING 1965, IN AVRA VALLEY.

at Three Points, a few miles west. A delineation of the approximate area of the storage reservoir in terms of the thickness of the permeable alluvium also is shown on figure 11. The designation of the thickness of permeable alluvium was made by Cooley and others (written communication, 1964). The area immediately adjacent to the mountain fronts, where the alluvium is less than 300 feet thick (fig. 11), was not included in the computation of the storage capacity. This is the so-called pediment area; the data available indicate that the alluvium probably is very thin here and that in a large part of the area it is above the water table. For the narrow band extending valleyward from the pediment area, an average thickness of 500 feet was used in the computation, although the thickness of the permeable sediments probably ranges from about 300 to 700 feet. Along the central part of the valley, where the alluvium may be saturated to depths of as much as 2, 000 feet, an arbitrary depth of 1, 000 feet was used in the computation of storage capacity. The depth-to-water contours for spring 1965 were used with the values of total thickness of the alluvium to determine the total thickness of the saturated material below the 1965 water level. From these data it was determined that the total volume of saturated material below the 1965 water table and above a depth of 1, 000 and 500 feet, respectively, was about 110 million acre-feet. In a previous section of this report it was shown that the storage coefficient of the aquifer in Avra Valley was about 0. 15. Thus, about 16. 5 million acre-feet of ground water is theoretically available from the storage reservoir in Avra Valley above the depths described. However, the actual volume of water that can be pumped from the ground-water reservoir may be less than the computed volume, depending upon the effectiveness of the removal of water from storage. Several physical factors, such as the depth of wells, distribution of wells, and rates and schedules of pumping, will affect the ability to withdraw the full amount of water that is available. The pattern of the cone of depression created by pumping and the quality of water at depth also will affect the amount of water that can be used.

Effects of Continued Withdrawal of Ground Water

As has been shown in the foregoing sections of this report, the present effect of ground-water withdrawal in Avra Valley is the regional lowering of the water table. Water levels have been measured, and the amount of ground water pumped has been calculated for the valley for many years. These historical data have been used to predict the status of the ground-water reservoir for 1970. The method used to make the prediction consists mainly of determining past trends in ground-water conditions, as indicated by water-level changes in individual wells, and projecting

these trends into the future. The projections are based on a hypothesized regimen of ground-water withdrawal.

The amount of ground water pumped annually in Avra Valley has been about the same for the last few years; therefore, for purposes of predicting the effects of continued withdrawal, it has been assumed that this rate and areal distribution will continue during the next 5 years — spring 1965 to spring 1970. The prediction of ground-water conditions in the valley is shown in the form of a depth-to-water map for spring 1970 (fig. 12). The reliability of the prediction of depth to water for 1970 will depend largely on how nearly the hypothesized pumping regimen conforms to actual pumping during the future 5-year period. Any deviation will directly affect the amount of change in the water levels in the aquifer. If the predictions were made for a longer period of time into the future, several other factors would affect the reliability. (1) Any differences in the permeability or transmissibility of the subsurface materials at greater depths would affect the rate of change in water levels. (2) Any unforeseeable changes in recharge rates, such as from excessive flooding, would reduce the rate of decline of the water level resulting from a like withdrawal of ground water by pumping. (3) Changes in the chemical quality of the water at greater depths must also be considered. If the ground water at greater depths is of poorer quality, there might be a shift of pumping to another area, or it might be necessary to pump larger amounts of water to leach away the effects of using water of poor quality for crop irrigation. All these factors would directly affect the accuracy and reliability of the predictions of future ground-water conditions in the area.

The map (fig. 12) shows that the predicted depth to water for spring 1970 is about 225 feet below the land surface at the north end of the valley and from 375 to 400 feet in the central part where ground-water withdrawal is greatest. At the south end of the valley the predicted depth to water is more than 450 feet at the southeast edge but is only about 200 feet near Three Points a few miles west. A comparison of the two maps — depth to water in spring 1965 (fig. 11) and predicted depth to water in spring 1970 (fig. 12) — indicates that about 3.8 million acre-feet of sediments will be dewatered in the 5-year period by the hypothesized amount of ground-water withdrawal. The average water-level decline during this time will be about 18 feet.

SUMMARY

Altar and Avra Valleys are the upper and lower parts, respectively, of a north-trending basin in the central part of Pima County. The

FIGURE 12.--PREDICTED DEPTH TO WATER FOR SPRING 1970 IN AVRA VALLEY.

two valleys are separated by an arbitrary dividing line perpendicular to Brawley Wash in Tps. 15 and 16 S. From this point Avra Valley extends northward to the Pima-Pinal County line and is separated arbitrarily from the Santa Cruz basin by the line that extends from the north tip of the Tucson Mountains to the Pima-Pinal County line.

Altar Valley is largely undeveloped and ground water is used mainly for stock and domestic purposes and a minor amount of irrigation. In Avra Valley some agricultural development using ground water took place as early as 1940, but extensive development of the ground-water resources did not begin until about 1950. At the present time (1965) about 30,000 acres of land is under cultivation in Avra Valley, and the annual withdrawal of ground water is about 115,000 acre-feet.

In Altar Valley the water levels have been affected only locally by the small amount of ground water withdrawn up to the present time. However, in Avra Valley the result of ground-water withdrawal is a regional lowering of the water table. In this area from 1955 to 1965, about 7.3 million acre-feet of sediments was dewatered owing to the pumping of about 1.2 million acre-feet of ground water. These data indicate that the coefficient of storage of the aquifer in Avra Valley probably is about 0.15. The average coefficient of transmissibility of the aquifer in the area, estimated from the specific capacities of wells and from well tests, is about 100,000 gpd per foot for the upper 500 to 700 feet.

Most of the water pumped in Avra Valley is withdrawn from storage. Calculations show that about 16.5 million acre-feet of ground water is available from storage in the aquifer. The saturated thickness of the alluvium used in the calculations was based on the depth to water in spring 1965 and the total thickness of the alluvial sediments in the valley, except that in the central part of the valley an arbitrary thickness of 1,000 feet was used. An estimate of the effect of continued withdrawal of ground water from storage, shown in the form of a prediction of the depth to water in spring 1970, indicates that an average decline of the water level of about 18 feet may take place in Avra Valley in the next 5 years. Data are not sufficient to make these determinations for Altar Valley.

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APPENDIX — BASIC DATA

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.

Well number: See figure 4 for description of well-numbering system.
Perforated interval: OH, open hole.
Land-surface altitude: Determined from Geological Survey topographic maps, unless otherwise indicated. L, spirit levels.
Water-level depth: R, reported.

Yield: R, reported.
Remarks: C 3, chemical analysis of water shown in table 3; C 4, chemical analysis of water shown in table 4; L, log of well shown in table 5. T = transmissibility in gallons per day per foot; computed after Thomasson and others, 1960.

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level: Depth below land surface (feet)	Water level: Date measured (mo/yr)	Pumping data: Yield (gpm)	Pumping data: Drawdown (feet)	Pumping data: Date measured (mo/yr)	Specific capacity (gallons per minute per foot of drawdown)	Remarks
(D-11-10)2cbd	...	...	16	...	1,895	184.6 185.3	12/63 1/65	...	...	...	...	
2dac	...	...	16	...	1,895	...	...	780	...	6/64	...	
4ddd	1951	320	16	155-314 OH 316-320	1,888 L	154.0 196.2	/51 1/65	610 370	... ...	7/56 7/62	...	
8aad	1941	650	20	140-386 OH 600-650	1,878 L	138.0 218.0	/42 1/65	1,600	37	8/41	43	C4; T = 73,000; abandoned.
8ddd	1951	443	18	154-430 OH 433-443	1,885 L	169.1 207.9	2/54 12/63	1,330 1,600	... ...	7/61 6/64	...	C4.
9dcc	1952	578	16	160-305 320-545	1,895	154.9 219.3	2/52 1/65	2,000 R 1,590	48 ...	/52 6/64	42	T = 71,000.
9ddd	1948	590	20	350-580	1,895	214.4 220.0	1/63 1/65	1,610 1,760	... ...	7/62 6/64	...	C3.
12add	1963	800	20	240-800	1,919 L	248.4 233.0	12/63 12/64	...	...	...	...	L.
12ccc	1947 1960	501 883	20	160-484	1,911	149.4 228.5	1/48 12/64	2,800 2,620	47 ...	... 9/48	60	C3, C4; T = 102,000.
13aaa	1947	520	20	160-508	1,925	154.4 242.5	1/48 12/64	3,950 3,570	42 ...	... 9/48	94	C3, C4; T = 160,000.
14dab	1951	395	18	82-395	1,915 L	165 R 231.8	4/51 1/65	1,380	...	6/64	...	C4.
15aad	1952	396	16	160-394	1,909 L	162.3 216.6	/52 1/65	1,700 R 1,170	28 ...	1/52 6/64	61	T = 104,000.
15cdd	1950	600	20	160-586	1,902 L	149 R 206.2	3/50 12/60	2,220	...	6/64	...	
15ddd	1952	333	20	165-322	1,909 L	168.3 221.7	3/53 1/65	3,200 R	32	1/52	100	T = 170,000.
17add	1940	500	20	150-500	1,884 L	136 R 204.5	/40 12/60	3,200 R 1,750	25 ...	/40 6/64	128	T = 218,000.
20dcc	1951	358	16	180-310 OH 320-358	1,921 L	175.8 235.0	3/53 1/65	1,800 R 702	30 ...	9/51 7/63	60	T = 102,000; abandoned.
20ddd	1952	529	20-18	170-529	1,909 L	225.4	1/64	2,200 R	20	11/52	110	T = 187,000; abandoned.
22add	1937	600	20	145-582	1,915 L	140.7 224.5	2/40 1/65	...	...	...	...	C4.
22ddd	1951	375	16	150-370	1,918 L	174.8 244.3	6/51 1/65	1,600 R 720	35 ...	5/51 7/63	46	C4; T = 78,000.

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level		Pumping data			Specific capacity (gallons per minute per foot of drawdown)	Remarks
						Depth below land surface (feet)	Date measured (mo/yr)	Yield (gpm)	Drawdown (feet)	Date measured (mo/yr)		
(D-11-10)23ddd	1947	370	20	160-350	1,933 L	160.2 240.0	/47 1/65	2,020	....	6/64	....	C4.
24aaa	1947	500	20	170-490	1,935 L	159.5 246.5	1/48 12/64	3,250 R 2,810	35	8/47 9/48	93	C3, C4; T = 158,000.
24bda	1951 1955	348 540	16	168-345	1,931 L	237.9 243.1	12/60 1/65	....	....	....	....	C4.
25dda	1949	600	20	175-586	1,953 L	209.9 265.3	2/52 1/65	2,240 1,830	....	8/60 6/64	....	C4.
26add	1952	628	20	260-612	1,939 L	190 R 229.7	12/52 12/60	1,825 1,970	....	8/60 7/63	....	
26bcb	1948	400	20	170-390	1,935 L	170.8 239.8	/49 1/65	....	....	....	....	C4.
27cdc	1947	310	16	....	1,922 L	170.9 234.4	2/54 1/65	865 928	....	8/60 7/63	....	C4.
27dab	1953	3,212	....	....	1,919	....	....	....	....	....	....	L; oil-test hole.
28bad	1963	700	20	....	1,915	250 R	1/64	....	....	....	....	C4.
33bda	1963	500	16	240-495	1,940	240.6	1/65	....	....	....	....	
(D-11-11)7ddd	1963	680	20	....	1,941 L	252.7	12/63	....	....	....	....	L.
11acc	1958	505	6	405-505	2,175	400 R	4/58	....	....	....	....	
16cdd	1937	538	20	180-520	1,966 L	172.5 279.0	3/40 12/64	2,750 R	26	1/47	106	C3, C4; T = 180,000.
16dcb	1951	512	20	200-498	1,968 L	194 R 248.4	2/51 12/59	....	....	....	....	
16dda	1962	500	18	....	1,980	375 R	8/64	....	....	....	....	
17ddd	1951	500	20	....	1,963 L	190.5	2/51	....	....	....	....	C4.
18ddd	1937	596	20	160-580	1,949	162.1 260.5	3/40 12/64	2,670	....	6/64	....	C3, C4.
20ccc	1947	442	20	170-420 OH 420-442	1,955	173.9 263.3	1/48 12/64	3,300 R	28	6/47	118	C3, C4; T = 201,000.
20dcd	....	....	....	....	1,964 L	266.0	12/63	....	....	....	....	
20ddd	1937	840	20	160-810 OH 827-840	1,967	171.1 272.5	3/40 12/64	2,690 R 2,430	22	1/47 6/64	122	C3; T = 207,000.
22ddc	1958	503	16	271-500	1,998	270 R	12/58	....	....	....	....	L.
25cdd	1952	620	16	160-620	2,021 L	236.1 286.4	/52 1/65	3,000 R	....	2/52	....	

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level: Depth below land surface (feet)	Water level: Date measured (mo/yr)	Pumping data: Yield (gpm)	Pumping data: Drawdown (feet)	Pumping data: Date measured (mo/yr)	Specific capacity (gallons per minute per foot of drawdown)	Remarks
(D-11-11)28aaa	....	400	....	....	1,984 L	258.5	12/59	....	....	....	....	
28acd	....	500	20	200-485	1,980 L	197.5 286.2	1/50 1/65	3,250 R	26	/49	125	C4; T = 212,000.
28ddd	....	500	20	200-485	1,981 L	201.0 291.3	1/50 11/64	3,250	29	/49	112	C4; T = 190,000.
31add	....	553	20	220-537	1,973 L	187.0 280.9	/49 1/65	....	....	....	....	C4.
32aad	1951	320	8	....	1,984	220 R 260.0	/51 12/59	....	....	....	....	
32add	....	400	12	192-395	1,975 L	194.7 278.1	/49 1/65	710 630	....	7/61 7/63	....	C4.
33bbd	1959	385	....	....	1,989 L	276.0	12/61	....	....	....	....	C4.
33daa	1951	440	12	220-400	1,997 L	220 R 266.6	5/51 12/59	1,300 R	....	5/51	....	C4.
34add	1939	510	20	200-498	2,008 L	188.9 294.6	3/40 12/64	....	....	....	....	C3, C4.
34ddd	1951	492	20	215-490	2,012 L	213 R 269.6	3/51 12/59	....	....	....	....	C4.
35adc	....	502	20	180-484	2,020 L	209.9 292.5	1/50 12/64	3,250 R	22	/49	148	C4.
35ddd	....	500	20	400-480	2,026 L	189.1 259.3	1/50 1/65	....	....	....	....	C4.
(D-12-10)1ccc	1951 1962	418 707	20	188-414	1,979 L	202.7 260.8	/52 1/65	....	....	....	....	
1cdd	1951	414	20	190-410	1,981 L	191 R 244.7	11/51 12/59	1,130 1,080	....	9/61 7/63	....	
3add	1962	714	....	....	1,971 L	260.3	12/62	....	....	....	....	
3ccc	1952	710	20	220-690	1,972 L	189.6 220.0	11/52 12/59	980 760	....	7/59 6/64	....	C4.
3dcd	1951	520	20	190-504	1,975 L	182.3 255.2	1/52 1/65	1,390	....	7/62	....	C4.
4abd	1960	1,200	....	....	1,964 L	232.9	12/61	....	....	....	....	
4cdd	1962	1,600	....	....	1,977 L	246.4	12/62	970 1,220	....	7/62 6/64	....	
4daa	1951	402	20	175-398	1,962 L	182.8	1/52	....	....	....	....	C4.

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level: Depth below land surface (feet)	Water level: Date measured (mo/yr)	Pumping data: Yield (gpm)	Pumping data: Drawdown (feet)	Pumping data: Date measured (mo/yr)	Specific capacity (gallons per minute per foot of drawdown)	Remarks
(D-12-10)4ddd	1951 1956	425 831	20	180-423	1,972 L	177 R	12/51	1,100 610	....	7/61 6/64	....	L.
9ddd	1951	508	20	180-504	1,984 L	168.6 228.6	1/52 1/65	2,600 R 1,220	100	11/51 6/64	26	T = 44,000.
12ccd	1951	344	20	185-336 OH 336-344	1,996 L	207.4 270.4	1/52 1/65	1,140	....	8/60	....	
14bcc	 1957	 602	10	....	2,004 L	175.7 237.1	10/42 1/65	1,390	....	6/64	....	
14cba	1957	602	....	....	2,007 L	227.9	12/59	....	....	....	....	
20add	1952	594	20	208-572	2,017 L	186.7 268.9	/52 1/65	1,770	....	7/62	....	
20ddd	1950	588	20	230-580	2,023 L	192.3 275.5	3/52 1/65	2,500 R 1,425	92	8/51 6/63	27	T = 46,000.
21ddd	1951	670	20	240-665	2,024 L	185.4 261.0	1/52 1/65	1,680 1,010	....	7/62 6/64	....	
23acd	1951	504	18-12	190-500	2,026 L	201.8 223.0	2/54 1/65	2,000 R 1,430	50	3/52 7/63	40	L; T = 68,000.
23ddc	1951	307	20	195-300	2,030	213.7 245.0	1/57 1/65	1,000 R 1,590	75	10/51 6/64	13	T = 22,000.
$24cdd_1$	1951	400	18	240-325	2,034	202.5 228.1	1/52 1/65	1,000 R	30	1/52	33	C4; T = 56,000.
$24cdd_2$	1954	785	18-16	....	2,034	247.9	1/65	1,320	....	7/63	....	
27dad	1952	600	20	250-582	2,042 L	196.6 256.6	/52 1/65	670	....	7/63	....	
28bcc	1952	500	20	250-488	2,040 L	204.5 255.9	3/52 12/58	700 R	33	....	21	T = 36,000; water-level and pumping data from American Smelting and Refining Co.
29abb	1942	290 420	8	.... OH 312-420	2,021 L	183.6	7/42	320	5	....	64	C3; T = 109,000; specific-capacity data from American Smelting and Refining Co.
29acb	1952	490	20	250-480	2,029 L	198.7 252.0	4/52 9/59	700 R	23	11/52	30	T = 51,000; water-level and pumping data from American Smelting and Refining Co.
29bbb	1952	522	20	250-510	2,034 L	204.0 284.0	4/52 1/65	700 R	13	9/55	54	T = 92,000; water-level and pumping data from American Smelting and Refining Co.
$30bbc_1$	1946	502	....	382-502	2,077 L	242 R 331.1	12/46 1/65	....	....	....	....	C4.

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level: Depth below land surface (feet)	Water level: Date measured (mo/yr)	Pumping data: Yield (gpm)	Pumping data: Drawdown (feet)	Pumping data: Date measured (mo/yr)	Specific capacity (gallons per minute per foot of drawdown)	Remarks
(D-12-10)30bbc2	1947	302	$12\frac{3}{4}$ -10	...	2,079	294.3	12/59	...	...	...	...	C4.
32ddd	1951	580	20	250-550 OH 560-580	2,068 L	209.7	1/52	2,380 R	120	7/51	20	C4; T = 34,000.
	1957	861	16	562-855		301.6	1/65	1,750	...	6/64	...	
33cdc	1962	1,900	...	...	2,068 L	290.4	12/62	2,160 1,390	... ...	7/62 6/64	...	C4.
33ddd	1951	600	20	260-535	2,068 L	202.5 287.8	/51 1/65	2,700 R 1,070	95 ...	3/51 6/64	28	C3, C4; T = 48,000.
(D-12-11)1caa	1952	...	...	...	2,035	203.2 251.0	1/53 1/65	...	...	...	...	
6acc	1949	4,950	...	...	1,975	...	...	...	...	...	...	Oil-test hole.
7bdd	1952	550	20	218-532	1,986 L	198.7 272.3	/52 1/65	1,710	...	7/62	...	
7cdd	1960	606	20	260-600 OH 604-606	1,990	270.8	12/61	1,820 1,740	... ...	7/62 6/64	...	C4; L.
9acc	1952	585	20	270-535 OH 550-585	2,013 L	231.6 320.5	/52 1/65	1,590	...	6/63	...	
12dda	1951	555	20	230-547	2,072 L	238.2 261.2	2/54 12/59	...	...	...	...	C4.
17add	1951	560	20	250-508 OH 526-560	2,005 L	215.4 307.2	1/52 1/65	1,540	...	6/64	...	
18cbc	1951	904	20	245-886	2,009	191.9 258.6	11/51 12/59	1,220 1,500	... ...	8/60 6/64	...	
18dcc	1951	385	16	180-380	2,010	210.3 268.0	6/52 1/65	1,600 R	...	7/51	...	C4.
18dcd	1941	474	12	190-400	2,013 L	206.0 278.2	/50 1/65	850 R 630	30 ...	5/47 7/62	28	C4; T = 48,000.
18ddc	...	462	12	210-462	2,010	210 R	6/48	750 R 640	40 ...	6/48 6/64	18	T = 31,000.
19aac	1948	470	12	...	2,015	207.7 264.8	11/48 12/59	1,000 R 620	35 ...	11/48 6/64	29	T = 49,000.
19bbc	1952	790	20	250-780	2,019 L	279.9	1/65	1,560	...	9/61	...	
20aaa	1951	375	16	200-370 OH 373-375	2,017 L	259.9 308.7	12/55 1/65	1,100 R 760	... ...	... 6/63	...	
20dda	1952	695	16	200-677 OH 677-695	2,048 L	260.2 339.9	11/52 1/65	3,000 R	...	8/52	...	C4; L.

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level		Pumping data			Specific capacity (gallons per minute per foot of drawdown)	Remarks
						Depth below land surface (feet)	Date measured (mo/yr)	Yield (gpm)	Drawdown (feet)	Date measured (mo/yr)		
(D-12-11)29add	1951	550	20	260-535	2,074 L	246.1 311.5	1/52 1/65	1,200 R	...	...	...	
30ddd	1951	725	...	...	2,055 L	208.4 252.7	2/53 1/65	570 620	... ...	5/52 8/60	...	
(D-13-10)4cdd	1951	601	20	222-601	2,090 L	218.0 308.8	1/52 1/65	1,540 1,060	... ...	7/61 6/64	...	
4ddd	1951 1957	600 855	20 16	250-592 555-802	2,091 L	218.2 262 R	1/52 2/57	1,185 1,420	... ...	6/51 6/64	...	C4.
5ddd	1957	587	20	237-587	2,090 L	271.0 314.4	1/58 1/65	1,800 R 1,130	30 ...	6/57 6/63	60	C4; T = 102,000.
6ddc	1951	420	20	207-415	2,084 L	218.5 310.2	/52 1/65	2,500 R	75	10/51	33	T = 56,000.
7acd	1962	501	12	285-496	2,100	279 R	11/62	...	...	...	...	
8ada	...	600	...	...	2,096 L	223.8 315.6	1/52 1/65	1,410 1,840	... ...	7/62 6/64	...	C4.
8ddd	1951	600	20	250-507 OH 522-600	2,105	228 R	6/51	3,000 R	80	5/52	38	T = 65,000.
9ddd	1951	700	20	300-685	2,119 L	236.6 329.7	/51 1/65	3,500 R 1,920	... ...	... 6/64	...	C4.
14bcc	1960	602	18	270-600	2,130	277.0 315.4	12/59 1/65	...	...	...	...	
14bcd	1963	1,570	18-12	600-1,490	2,125	...	...	...	...	...	...	
14cdc	1950	596	20	290-586	2,143 L	239.1 329.7	/50 1/65	2,700 R	...	2/50	...	L.
15ddd	1951	814	20	285-805	2,144 L	241.6 307.8	/51 12/59	1,540 1,060	... ...	6/51 6/64	...	C4.
16ddd	1951	600	20	285-567 OH 582-600	2,143 L	257.2 347.1	1/52 1/65	1,400 1,060	... ...	7/59 6/64	...	C4.
20ccd	1952	515	20	200-475 OH 494-515	2,148 L	262.2 353.3	1/52 1/65	2,300 R	...	3/52	...	C4.
22ddd	1952	590	20	300-580	2,169 L	265.4 356.7	1/52 1/65	1,590 1,840	... ...	8/60 6/64	...	
23dcc	1952	700	20	255-650	2,167 L	267.7 350.6	3/52 1/65	2,500 R	45	3/52	56	T = 95,000.
24dcc	1952	575	20	247-564	2,165 L	252.5 329.9	1/52 1/65	2,500 R	50	2/52	50	T = 85,000.

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level		Pumping data			Specific capacity (gallons per minute per foot of drawdown)	Remarks
						Depth below land surface (feet)	Date measured (mo/yr)	Yield (gpm)	Drawdown (feet)	Date measured (mo/yr)		
(D-13-10)25acd	1951 1958	662 1,140	20 16	300-645 652-1,047	2,180 L	253.2 338.3	1/52 1/65	2,800 R 1,330	31	1/59 6/64	90	T = 153,000.
25bdc	1958	1,090	20	350-1,017 OH 1,028-1,090	2,175	309.7	12/59	2,500 R 1,640	35	1/59 7/62	71	L; T = 121,000.
25dcc	1950	685	20	200-600 OH 600-685	2,190 L	252 R 324.2	10/50 12/59	2,800 R 1,550	26	10/50 6/64	108	C4; T = 184,000.
26ccd	1951	700	20	310-685	2,192 L	270.7 364.3	1/52 1/65	2,400 R 1,500	....	.... 6/64	....	
26dcd	1953	705	20	319-695	2,188	288.9	2/54	2,500 R	25	3/53	100	T = 170,000.
(D-13-11)4cad	....	354	6	OH 335-354	2,169 L	329.3	1/65	50 R	7	12/53	7	
11acc	1959	520	....	....	2,394 L	267.6 288.3	12/59 1/65	....	....	....	....	C4.
16dca	1956	504	8	397-500	2,290 L	380 R 421.5	12/56 1/65	....	....	....	....	L.
18dd	1953	....	....	....	2,152 L	234.6 313.5	/49 1/65	....	....	....	....	C4.
30ccc	1952	682	20	200-600 OH 600-682	2,186 L	262.3 340.5	1/53 1/65	2,400 R 1,700	21	5/52 6/64	114	T = 194,000.
31ccc	1952	736	20	234-736	2,212 L	276.2 348.6	3/53 1/65	2,400 R 1,810	....	.... 6/63	....	L.
31cdd	1951	705	20	270-705	2,213 L	343.8	1/65	2,100	....	6/64	....	
32daa	1957	450	....	....	2,237 L	316.7 354.0	/57 1/65	....	....	....	....	
34cdd	1964	560	6	400-560	2,350	441 R 462.2	3/64 1/65	....	....	....	....	C4.
(D-14-10)23dca	1950	400	8	....	2,323 L	334.8 363.6	9/52 1/65	18 R	....	....	....	C4.
25caa	....	400	8	....	2,331 L	308.3 326.7	4/40 1/65	....	....	....	....	C3, C4.
(D-14-11)2ccc	1958	582	6	453-565 OH 568-582	2,418 L	463 R 487.4	3/58 1/65	....	....	....	....	C4.
4cad	1952	581	16	200-561 OH 561-581	2,261 L	294.4 349.4	3/53 1/65	1,150 1,350	....	7/59 6/64	....	
5ccd	1951	616	20	300-566 OH 576-616	2,235 L	278.2 333.8	3/53 1/65	1,380	....	7/62	....	
6ccd	1952	635	20	280-635	2,231 L	274.0 345.0	1/52 1/65	2,100 R 1,390	46	1/52 6/64	46	T = 78,000.

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level		Pumping data			Specific capacity (gallons per minute per foot of drawdown)	Remarks
						Depth below land surface (feet)	Date measured (mo/yr)	Yield (gpm)	Drawdown (feet)	Date measured (mo/yr)		
(D-14-11)6dcc	1952	700	20	240-641 OH 641-700	2, 238 L	283. 1 357. 2	3/53 1/65	2, 200 R 2, 250	....	.... 6/64	....	
7bad	1951	700	20	300-700	2, 242 L	288. 0 350. 0	1/53 1/65	2, 100 R 1, 270	61	11/51 7/62	34	C4; T = 58, 000.
8ccc	1951	590	20	300-580	2, 258 L	280. 2 336. 4	1/52 1/65	2, 400 R 1, 440	....	12/51 6/64	....	L.
9dbd	1941	325	10	....	2, 263 L	282. 3 334. 4	/49 1/65	....	....	....	....	C3.
13ccc	....	604	8	....	2, 390	385 R 403. 4	11/55 12/63	....	....	....	....	C4.
13ddd	1955	480	....	....	2, 457 L	453. 2	11/55	....	....	....	....	
19bab	1956	411	....	276-391	2, 286 L	342. 0	1/65	....	....	....	....	C4.
27aad	....	....	....	....	2, 313 L	295. 2 315. 9	3/54 1/65	....	....	....	....	
28dcc	1951	495	20	285-490	2, 315	307. 5 316. 4	2/54 1/65	3, 000 R 1, 220	55	4/51 6/64	55	T = 94, 000.
29ccc	....	....	20	....	....	295 R	1/53	2, 600	65	1/53	40	
29ddd	1952	542	20	350-527	2, 320 L	295. 7 322. 9	/53 1/65	2, 700 R 1, 530	50	12/52 7/61	54	C4; T = 92, 000.
33ccc	1953	712	20	240-697 OH 697-712	2, 337 L	308. 0 320. 8	2/54 1/65	3, 050 R 1, 120	75	1/53 6/64	41	C3, L; T = 70, 000.
33dcd	1953	670	20	350-650	2, 329 L	289. 9	3/53	2, 500 R 1, 860	50	1/53 6/64	50	C4; T = 85, 000.
34aad	1952	512	20	285-510	2, 317	287. 0 311. 5	8/52 1/65	2, 600 R 2, 090	89	7/52 6/63	29	T = 49, 000.
34bbc	1951	535	20	280-530	2, 311 L	296. 1 307. 4	2/54 1/65	2, 800 R 1, 100	90	6/51 6/64	31	C4; T = 53, 000.
34ccc	1953	620	20	350-600	2, 322 L	293. 2 316. 3	1/54 1/65	2, 450 R 1, 640	50	3/53 6/64	49	T = 83, 000.
(D-14-12)17bb	1934	113	6	....	2, 620	78. 7 93. 3	3/40 3/54	....	....	....	....	C3.
34cc	1932	322	6	....	2, 533 L	112. 3 109. 8	3/40 1/65	....	....	....	....	C4.
36adc	1929	165	6	....	2, 592 L	95. 6 125. 8	3/40 1/54	....	....	....	....	

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level		Pumping data			Specific capacity (gallons per minute per foot of drawdown)	Remarks
						Depth below land surface (feet)	Date measured (mo/yr)	Yield (gpm)	Drawdown (feet)	Date measured (mo/yr)		
(D-15-10)28cdd	....	640	18-16	240-640	2, 529 L	161. 8 169. 6	2/54 1/65	2, 600 R 1, 820	50	1/53 7/62	52	C3, C4; T = 88, 000; gamma-ray and neutron log.
33bcc	1951	710	16	220-710	2, 531	163. 7	2/54	1, 300 R 800	145	4/51 6/64	9	C4.
33cbc	1952	783	18	240-783	2, 540	155. 6 196. 2	/53 1/65	2, 400 R 1, [illegible]0	120	9/52 6/63	20	C4, L; T = 34, 000.
33dbc	1952 1957	353 616	20	OH 302-353	2, 531 L	157. 2	3/53	1, [illegible]00 R 1, 160	128	3/52 7/61	8	C4. May have been drilled deeper.
34daa	1959	285	8	190-270 OH 270-285	2, 535	204. 5	1/65	....	....	....	....	
35aa	1919	350	6	....	2, 531 L	214. 2 223. 5	3/40 1/65	....	....	....	....	C3.
(D-15-11)5ccd	1953	712	20	240-697	2, 368 L	281. 1 324. 1	3/53 2/65	3, 000 R	40	1/53	75	C4; T = 128, 000; recorder installed October 1963; gamma-ray log.
11add	1953	588	20	330-585	2, 388 L	337. 5 352. 3	1/54 1/65	2, 700 R 1, 243	85	1/53 7/62	32	L; T = 54, 000.
12dca	1942	550	8	....	2, 416 L	362 R 382. 1	6/42 1/65	....	....	....	....	C4.
15bbb	1965	2, 000	....	....	2, 390	....	....	....	....	....	....	Test hole for city of Tucson. Static water level: 311 feet, testing zone below 1, 865 feet; 304 feet, testing zone 1, 100-1, 200 feet.
19bbb	1965	1, 540	....	....	2, 430	....	....	....	....	....	....	Test hole for city of Tucson. Static water level: 137 feet, testing zone below 1, 050 feet; 309 feet, testing zone 760-1, 045 feet.
22ddd	1965	2, 607	....	....	2, 519	....	....	....	....	....	....	Test hole for city of Tucson; L.
32ddc	....	490	....	....	2, 631 L	430. 3 431. 8	/49 1/65	....	....	....	....	
(D-16-9) 14dbb	....	....	6	....	2, 658 L	148. 0 147. 4	/52 1/65	....	....	....	....	
15aad	....	175	....	....	2, 665	145. 5 142. 8	10/48 3/65	....	....	....	....	
15dbb	....	300	....	....	2, 687 L	161. 5 157. 7	10/48 1/65	....	....	....	....	C4.
21cdc	 1957	282 382	 6	....	2, 818 L	270. 9 270. 3	10/48 1/65	....	....	....	....	

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level		Pumping data			Specific capacity (gallons per minute per foot of drawdown)	Remarks
						Depth below land surface (feet)	Date measured (mo/yr)	Yield (gpm)	Drawdown (feet)	Date measured (mo/yr)		
(D-16-9) 24dac	1955	240	20	....	2, 651 L	147. 7 151. 9	9/55 3/65	....	....	....	....	
24ddc	....	....	....	....	2, 650	152. 9 152. 7	2/64 3/65	....	....	....	....	
25cbc	....	....	....	....	2, 690	157. 4 159. 1	2/64 3/65	....	....	....	....	
27aaa	1932	214	....	....	2, 725 L	194. 0 183. 5	9/40 1/65	....	....	....	....	
28dac	1957	1, 007	20	....	2, 838 L	283. 1 283. 3	10/57 1/65	....	....	....	....	C4, L.
29caa	....	....	....	....	2, 925 L	379. 0 370. 1	2/31 1/65	....	....	....	....	C4.
(D-16-10)4baa	1945	400	20	160-220	2, 540	158. 7	10/45	1, 500 R	30	6/45	50	T = 85, 000.
4bad	....	400	....	....	2, 546 L	152. 0 168. 1	3/47 1/65	....	....	....	....	C4.
4ddd	1965	1, 613	....	....	2, 610	....	....	....	....	....	....	Test hole for city of Tucson. Static water level: 277 feet, testing zone below 1, 200 feet; 220 feet, testing zone 975-1, 150 feet; 231 feet, testing zone 690-900 feet. L.
5ddd	1952	295	16	175-252 OH 252-295	2, 572 L	161. 7 167. 9	3/53 1/65	....	....	....	....	
6dac	....	....	....	....	2, 572 L	164. 1 177. 3	4/49 1/65	....	....	....	....	
8bdd	1952	232	16	163-220 OH 228-232	2, 582 L	152. 2 156. 5	3/53 1/65	....	....	....	....	
10ddd	....	351	....	....	2, 732 L	317. 4 311. 9	/48 1/65	....	....	....	....	C4.
18ccc	1960	432	16	....	2, 633 L	139. 2	5/60	....	....	....	....	
19cac	1960	455	16	....	2, 645 L	151. 2 155. 8	5/60 1/65	....	....	....	....	
19cca	....	180	8	....	2, 652 L	158. 0 154. 4	6/51 1/65	....	....	....	....	C4.
23dcd	1962	714	6	....	3, 057 L	647. 2 644. 3	/63 1/65	....	....	....	....	
29ada	....	....	6	....	2, 835 L	344. 6 345. 0	2/57 1/65	....	....	....	....	

Table 2.--Records of selected wells, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date completed (year)	Depth of well (feet)	Casing diameter (inches)	Perforated interval (feet below land surface)	Land-surface altitude (feet above mean sea level)	Water level: Depth below land surface (feet)	Water level: Date measured (mo/yr)	Pumping data: Yield (gpm)	Pumping data: Drawdown (feet)	Pumping data: Date measured (mo/yr)	Specific capacity (gallons per minute per foot of drawdown)	Remarks
(D-16-10)30ddd	1960	500	...	...	2,792 L	289.2 284.8	1/61 1/65	...	...	...	...	
34bab	...	875	...	...	3,096 L	603.8	1/65	...	...	...	...	L.
35ccb	1940	830	6	...	3,252 L	765.0 763.8	/40 1/65	...	...	...	...	C4.
(D-16-11)8ccc	1946	754	6	690-754	2,906 L	690.0 683.8	/46 1/65	...	...	...	...	Not shown on map.
(D-17-9)1ccb	1946	500	20	...	2,751 L	184.9 186.5	9/55 1/64	...	...	...	...	L.
1dbc	1960	286	6	...	2,790 L	231.4 227.6	1/61 1/65	...	...	...	...	
23ada	...	...	...	...	2,844 L	242.3 237.6	/51 1/65	...	...	...	...	C4.
35aac	1943	416	...	...	2,880 L	252.4 249.1	5/52 1/65	...	...	...	...	C4, L.
(D-17-10)10ccc	...	905	7	735-905	3,289 L	717.6 715.1	6/52 1/62	...	...	...	...	C4, L.
(D-18-9)2dca	1960	...	...	...	2,955 L	305.3 298.3	1/61 1/65	...	...	...	...	
11baa	...	...	...	...	2,915 L	250.8 248.7	/57 1/65	...	...	...	...	C4.
11bcc	1959	610	...	...	2,932 L	251.4 255.9	1/60 1/65	...	...	...	...	
30ada	1936	425	8	...	3,160 L	391.5 391.8	/51 1/62	...	...	...	...	L.
(D-19-8)13cad	...	...	...	...	3,392 L	544.7 545.5	/51 1/65	...	...	...	...	C4.
(D-19-9)3acb	...	376	...	...	3,055 L	332.0 328.8	/58 1/65	...	...	...	...	C4.
15ada	...	571	...	...	3,101 L	339.9 330.5	/58 1/65	...	...	...	...	C4.
(D-20-9)17aba	...	340	...	...	3,254 L	277.6 272.4	/58 1/62	...	...	...	...	
(D-21-8)16adb	1956	505	...	...	3,507 L	400.0 395.5	4/57 3/65	...	...	...	...	
27ada	...	400	...	...	3,465 L	317.5 317.2	/51 3/65	...	...	...	...	C4.

Table 3.--Selected drillers' logs of wells in Avra and Altar Valleys, Pima County, Ariz.

	Thickness (feet)	Depth (feet)
(D-11-10)12add		
Sand rock and boulders	40	40
Fine gravel	36	76
Fine gravel with some clay	31	107
Coarse sand and pea gravel	30	137
Medium to coarse sand and pea gravel with clay	61	198
Coarse sand and pea gravel with clay	29	227
Medium to coarse sand and pea gravel with clay	31	258
Medium to coarse sand with clay and some gravel	10	268
Medium to coarse sand with clay	79	347
Fine to coarse sand with clay	31	378
Clay with coarse sand	30	408
Clay and sand	60	468
Clay and boulders	4	472
Sand with little clay	31	503
Medium to coarse sand	17	520
Medium to coarse sand with little clay	13	533
Medium to coarse sand	12	545
Fine to coarse sand	35	580
Medium to coarse sand	15	595
Clay and sand streaks	91	686
Clay with medium to coarse sand	14	700
Fine to coarse sand with clay	17	717
Fine to medium sand with clay	30	747
Clay with sand	31	778
Clay with fine to medium sand	22	800
TOTAL DEPTH		800
(D-11-10)27dab		
Top soil—valley fill	44	44
Sand and gravel	106	150
Sandy clay and silt	106	256
Sandy gravel—water	141	397
Sand and gravel	13	410
Sandy clay	10	420
Sandy clay	30	450
Heavy clay	40	490
Hard sandy lime	20	510
Gravelly clay	10	520
Fine gravelly clay	30	550
Sandy lime	50	600
Clay and sand	50	650
Sandy clay	30	680
Reddish sandy clay	40	720
Clay	40	760
Red sandy clay	60	820
Sandy shale	10	830
Sandy clay	10	840
Fine sandy clay	50	890
Fine sandy clay	60	950
Reddish fine sandy clay	100	1,050
Water sand (may be second water table)	10	1,060
Red clay	10	1,070
Water sand	10	1,080
Light colored sandy clay	10	1,090
Coarse water sand	20	1,110
Light colored clay	20	1,130
Coarse water sand	30	1,160
Light colored sandy clay	10	1,170
Coarse water sand	250	1,420
Light colored sandy clay	80	1,500
Washed gravel, sandy	20	1,520
Washed gravel, sandy	10	1,530
Dark coarse brown sandy lime	20	1,550
Fine light colored sand	10	1,560
Dark coarse sand	40	1,600
Brown sandy lime	20	1,620
Shale showing lime	15	1,635
Sandy lime, some shale	15	1,650
Sandy lime, specks of mica	8	1,658
Brown sand, shell and limy	124	1,782
Cemented sand, streaks of lime	78	1,860
Sandy lime showing specks of pyrite	80	1,940
Sandy lime with some shale	90	2,030
Hard drilling, fine sand	30	2,060
Fine sand showing lime	15	2,075
Fine sandy silt showing lime	310	2,385
Hard sand and heavy clay	45	2,430
Hard sand with streaks of clay	155	2,585
(D-11-10)27dab—Continued		
Sand and gravel	25	2,610
Sand and streaks of shale	70	2,680
Sandy with streaks of shale	35	2,715
Hard sand	50	2,765
Hard sand—trace of lime	30	2,795
Hard lime	35	2,830
Hard sandy lime	68	2,898
Hard gray sand	69	2,967
Red rock—very hard (top of red beds 2,967)	43	3,010
Red beds	122	3,132
Coring in red beds	16	3,148
Red beds	64	3,212
TOTAL DEPTH		3,212
(D-11-11)7ddd		
Top soil	15	15
Hard pan	15	30
Sand	15	45
Sand and boulders	34	79
Conglomerate with boulders and pea gravel	31	110
Pea gravel	30	140
Pea gravel with coarse sand and clay	31	171
Clay with coarse sand and gravel	39	210
Clay with medium to coarse sand	21	231
Clay and gravel with medium sand	9	240
Clay and conglomerate	23	263
Clay and coarse sand	55	318
Clay with medium to coarse sand	12	330
Clay with fine to medium sand	22	352
Clay with medium to coarse sand	31	383
Clay with medium to coarse sand	30	413
Sand and clay	30	443
Coarse sand with clay and pea gravel	64	507
Coarse sand with clay	53	560
Clay with sand	80	640
Sand with clay	10	650
Medium sand with clay	20	670
Sand with very little clay	10	680
TOTAL DEPTH		680
(D-11-11)22ddc		
Soil	6	6
Loose sand and gravel	42	48
Large boulders and gravel, loose	142	190
Red clay	20	210
Loose boulders and gravel	25	235
Loose sand—gravel—some clay	35	270
Sand and gravel—water at 270 feet	15	285
Clay—very little gravel	35	320
Cemented gravel	30	350
Yellow sticky clay	70	420
Yellow clay—sand and gravel	55	475
Sticky yellow clay	10	485
Cemented gravel	18	503
TOTAL DEPTH		503
(D-12-10)4ddd		
Soil	5	5
Caliche	35	40
Rocky shale	5	45
Muddy gravel	75	120
Conglomerate	34	154
Shale	28	182
Clean gravel and water	40	222
Sandy shale	11	233
Coarse gravel and water	5	238
Shale	12	250
Clean gravel and water	6	256
Shale	32	288
Gravel and water	40	328
Laminations of cemented sand and loose sand and water	13	341

Table 3. --Selected drillers' logs of wells in Avra and Altar Valleys, Pima County, Ariz. —Continued

(D-12-10)4ddd—Continued	Thickness (feet)	Depth (feet)
Shale	7	348
Gravel and water	9	357
Shale	15	372
Hard conglomerate	13	385
Gravel and water	2	387
Conglomerate	31	418
Clean gravel and water	4	422
Hard conglomerate	3	425
Deepening		
Tight conglomerate	22	447
Clean coarse gravel and water	11	458
Tight conglomerate	11	469
Clean gravel and water	6	475
Sticky clay	252	727
Clean gravel and water	4	731
Conglomerate	9	740
Clean coarse gravel and water	18	758
Tight conglomerate	73	831
TOTAL DEPTH		831

(D-12-10)23acd	Thickness (feet)	Depth (feet)
Soil	4	4
Caliche	4	8
Sand	2	10
Cemented gravel	7	17
Caliche	11	28
Dirty sand	82	110
Rocky shale	87	197
Gravel and water	13	210
Shale	5	215
Clean gravel and water	15	230
Shale	35	265
Muddy gravel and water	20	285
Shale	10	295
Clean coarse gravel and water	10	305
Shale	20	325
Fine sand and water	15	340
Shale	40	380
Clean fine sand and water	10	390
Shale	97	487
Clean coarse gravel and water	5	492
Hard sandstone	12	504
TOTAL DEPTH		504

(D-12-11)7cdd	Thickness (feet)	Depth (feet)
Soil	3	3
Red clay	67	70
Clay, gravel	20	90
Dry gravel	25	115
Red clay	7	122
Clay, gravel	83	205
Cemented gravel, some water (perched)	31	236
Yellow clay	29	265
Muddy gravel, water	20	285
Hard conglomerate	35	320
Clean gravel, water	17	337
Clay, gravel	38	375
Clean gravel, water	15	390
Sticky hardpan	30	420
Clean gravel, water	7	427
Red clay	13	440
Tight conglomerate	20	460
Clean sand, water	26	486
Clay, gravel	59	545
Clean gravel, water	17	562
Tight conglomerate	44	606
TOTAL DEPTH		606

(D-12-11)20dda	Thickness (feet)	Depth (feet)
Surface soil	22	22
Sand with streaks of clay	159	181
Clay with streaks of gravel	136	317

(D-12-11)20dda—Continued	Thickness (feet)	Depth (feet)
Clay	22	339
Clay with streaks of gravel	44	383
Sand and boulders with streaks of clay	23	406
Clay with streaks of sand	45	451
Sand and boulders with streaks of clay	65	516
Sand and boulders	22	538
Clay	18	556
Sand and gravel	50	606
Sandy clay	18	624
Sand and gravel	54	678
Hard clay or shale	17	695
TOTAL DEPTH		695

(D-13-10)14cdc	Thickness (feet)	Depth (feet)
Soil and caliche	14	14
Gravel	6	20
Clay and gravel	36	56
Gravel	4	60
Clay and gravel	33	93
Gravel	5	98
Clay	24	122
Clay and gravel	43	165
Gravel	7	172
Clay and gravel	22	194
Clay	63	257
Gravel, 5 inches	5	262
Clay	2	264
Gravel, 1 inch	4	268
Clay	4	272
Gravel, 1 inch	14	286
Clay	2	288
Gravel, 4 inches	8	296
Clay	10	306
Gravel, 2 inches	2	308
Clay	8	316
Gravel, 4 inches	20	336
Clay	18	354
Gravel, 2 inches	2	356
Clay	34	390
Gravel, 4 inches	6	396
Clay and sandstone	4	400
Gravel, 4 inches, with streaks of cemented sand and clay	110	510
Clay	14	524
Gravel, 5 inches	3	527
Clay	7	534
Gravel, 2 inches	8	542
Clay	14	556
Gravel, 3 inches	4	560
Clay	14	574
Gravel, 3 inches	6	580
Clay	8	588
Gravel, 2 inches	4	592
Clay	4	596
TOTAL DEPTH		596

(D-13-10)25bdc	Thickness (feet)	Depth (feet)
Top soil	6	6
Sand	4	10
Sandy clay	55	65
Clay and gravel	95	160
Sandy clay	130	290
Sand and gravel	15	305
Clay and gravel	45	350
Gravel	8	358
Clay and gravel	12	370
Gravel	10	380
Clay and gravel	90	470
Cemented sand and gravel	20	490
Clay and gravel	202	692
Cemented gravel	8	700
Sandstone	10	710
Clay and gravel	20	730
Sand and gravel	50	780
Cemented gravel	25	805

Table 3.--Selected drillers' logs of wells in Avra and Altar Valleys, Pima County, Ariz.—Continued

	Thickness (feet)	Depth (feet)
(D-13-10)25bdc—Continued		
Clay and gravel	70	875
Gravel	11	886
Clay and gravel	77	963
Conglomerate	127	1,090
TOTAL DEPTH		1,090
(D-13-11)16dca		
Sandy soil	3	3
Conglomerate	97	100
Boulders	64	164
Gravelly clay	96	260
Conglomerate	80	340
Hard conglomerate shell	5	345
Gravelly clay	52	397
Soft clayey gravel and water	10	407
Gravelly clay	13	420
Muddy gravel and water	75	495
Clay	9	504
TOTAL DEPTH		504
(D-13-11)31ccc		
Clay	30	30
Hard sand and boulders	223	253
Soft sand	187	440
Sand and streaks of clay	160	600
Hard cemented sand	18	618
Sand	57	675
Hard cemented sand and streaks of soft sand	61	736
TOTAL DEPTH		736
(D-14-11)8ccc		
Surface soil	4	4
Caliche and boulders	6	10
Clay and sharp gravel	80	90
Sandy clay	90	180
Gravel	20	200
Hard clay with layers of gravel and boulders	100	300
Sand (first water)	20	320
Gravel and boulders with streaks of clay	100	420
Hard packed clay and gravel with layer of cemented material	170	590
TOTAL DEPTH		590
(D-14-11)33ccc		
Clay and boulders	40	40
Fine sand	60	100
Sand and boulders	200	300
Streaks of shale and boulders	45	345
Sand, probably water sand	155	500
Hard sand	118	618
Coarse gravel	79	697
Hard sand	15	712
TOTAL DEPTH		712
(D-15-10)33cbc		
Top soil	5	5
Sand	7	12
Coarse gravel	79	91
Boulders	53	144
Boulders, clay streaks	53	197
Clay boulders	27	224
Boulders, shale	40	264
Hard boulders	27	291
Clay	5	296
Hard sand	9	305
Sand st. of boulders	14	319
Medium hard brown shale	61	380

	Thickness (feet)	Depth (feet)
(D-15-10)33cbc—Continued		
Sand	14	394
Conglomerate	6	400
Hard brown shale	70	470
Boulders	4	474
Hard brown shale	8	482
Sand	16	498
Shale	42	540
Sand boulders	21	561
Sand	6	567
Boulders and conglomerate	10	577
Sand boulders	60	637
Shale and sand	34	671
Sand boulders	112	783
TOTAL DEPTH		783
(D-15-11)11add		
Soil	10	10
Sandy clay	96	106
Clay with streaks of sand	29	135
Sticky clay	10	145
Sandy clay	37	182
Sticky clay	7	189
Sandy clay	9	198
Soft sandy shale	53	251
Hard clay	8	259
Sandy clay	6	265
Clayey gravel	75	340
Hard clay	6	346
Sand, gravel, and water	27	373
Sandy clay	9	382
Sand, coarse gravel, and water	26	408
Conglomerate	24	432
Clayey gravel and water	43	475
Sandy clay	10	485
Rocky conglomerate	10	495
Muddy sand, gravel, and water	3	498
Hard rocky conglomerate	23	521
Muddy gravel and water	11	532
Rocky conglomerate	56	588
TOTAL DEPTH		588
(D-15-11)22ddd		
Fill	3	3
Red and yellow caliche	158	161
Sand and fine gravel	5	166
Caliche and gravel	80	246
Yellow caliche and gravel	150	396
Water gravel and caliche streaks	200	596
Caliche and gravel	100	696
Gravel and caliche, hard streaks	70	766
Hard sand streaks and clay streaks	43	809
Sand and fine clay streaks	197	1,006
Hard sand and clay streaks	150	1,156
Hard sand. Some soft streaks and gravel	55	1,211
Hard sand and caliche	50	1,261
Hard sand. Soft streaks and clay streaks	170	1,431
Sandstone and hard streaks	60	1,491
Sandstone. Soft sandy streaks and gravel streaks	205	1,696
Hard sand	100	1,796
Hard sandstone	15	1,811
Hard streaks	80	1,891
Clay and sand streaks	25	1,916
Sand and clay streaks. Sticky clay	130	2,046
Hard sand	50	2,096
Hard and soft sand streaks. Sticky clay	95	2,191
Hard sand streaks and shale streaks. Sticky clay	135	2,326
Sand. Hard streaks and clay streaks	120	2,446
Hard sand streaks and clay	70	2,516
Hard sand. Clay streaks	55	2,571
Malpais. Hard	29	2,600
Cored. Recovered hard conglomerate	7	2,607
TOTAL DEPTH		2,607

Table 3. --Selected drillers' logs of wells in Avra and Altar Valleys, Pima County, Ariz. ——Continued

	Thickness (feet)	Depth (feet)
(D-16-9)28dac		
Clay	175	175
Clay	60	235
Conglomerate	15	250
Sandy clay, conglomerate	25	275
Conglomerate, making water at 300	40	315
Conglomerate and sandy clay	30	345
Sandy clay	20	365
Sandy clay and gravel	25	390
Clean gravel	15	405
Cemented gravel	58	463
Gravel	62	525
Clay and gravel	30	555
Cemented gravel	20	575
Coarse water gravel	20	595
Cemented gravel	105	700
Coarse gravel	307	1, 007
TOTAL DEPTH		1, 007
(D-16-10)4ddd		
Hard caliche rock	151	151
Sand and hard streaks	245	396
Hard and soft streaks. Sand	140	536
Hard sand	150	686
Hard and soft streaks of clay and sand	400	1, 086
Hard streaks and sand	120	1, 206
Soft sand	270	1, 476
Hard rock	10	1, 486
Soft sand	20	1, 506
Hard rock and clay	107	1, 613
TOTAL DEPTH		1, 613
(D-16-10)34bab		
Soil	6	6
Clay gravel	18	24
Cemented rocks	31	55
Sandy gravel, clay	15	70
Sand gravel	10	80
Sandy clay, gravel	80	160
Sand	10	170
Sandy clay, gravel	180	350
Clay gravel	135	485
Sand, gravel, little clay	90	575
Clay gravel, rocks, water	55	630
Muddy gravel	45	675
Rocky gravel	20	695
Muddy sand	30	725
Cemented conglomerate	10	735
Muddy sand, gravel	110	845
Solid rock granite	30	875
TOTAL DEPTH		875

	Thickness (feet)	Depth (feet)
(D-17-9)1ccb		
Soil	20	20
Dirty gravel	55	75
Clay	110	185
Muddy sand and water	10	195
Clean gravel and water	50	245
Tight sticky conglomerate	255	500
TOTAL DEPTH		500
(D-17-9)35aac		
Loose sandy soil	3	3
Hard clay and gravel	32	35
Brown clay	7	42
Gravel, some clay	16	58
Yellow clay and gravel	17	75
Yellow clay and boulders	20	95
Yellow sandy clay	25	120
Gravel, little clay	14	134
Clay, some boulders	22	156
Gravel, little clay	9	165
Clay and gravel	20	185
Loose dry sand	20	205
Gravel and clay	25	230
Clay, some boulders	38	268
Loose sandy clay (water strata)	3	271
Sticky clay, slight water	9	280
Cemented gravel, some water	10	290
Sticky clay	20	310
Hard leather clay	5	315
Hard loose sandy clay	7	322
Hard leather clay	94	416
TOTAL DEPTH		416
(D-17-10)10ccc		
Sand	200	200
Gila Conglomerate	535	735
Conglomerate, looser formation	170	905
TOTAL DEPTH		905
(D-18-9)30ada		
Soil	3	3
Gravel, clay, and boulders	272	275
Cemented sand, gravel	122	397
Gravel, sand, little silt	18	415
Light blue clay	10	425
TOTAL DEPTH		425

Table 4.—Chemical analyses of ground water, Avra Valley, Pima County, Ariz.

[Analytical results in parts per million except as indicated]

Well number	Date of collection	Depth (feet)	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
															Parts per million	Tons per acre-foot	Calcium, magnesium	Noncarbonate				
(D-11-10)9ddd	9/ 1/48	590	78	31	43	6.6	62		198	0	76	19	0.2	2.0	337	0.46	134	0	.....	......	539	......
12ccc	9/ 1/48	501	77	....	....	....	......	......	185	0	....	19	......	......	.....	......	....	......	.....	......	501	......
13aaa	9/ 1/48	520	77	....	....	....	......	......	177	0	....	20	......	......	.....	......	....	......	.....	......	489	......
24aaa	9/ 1/48	500	75	....	....	....	......	......	183	0	....	22	......	......	.....	......	....	......	.....	......	530	......
(D-11-11)16cdd	9/ 2/48	538	76	....	....	....	......	......	149	0	....	16	......	......	.....	......	....	......	.....	......	394	......
18ddd	9/ 2/48	596	76	....	....	....	......	......	161	0	....	24	......	......	.....	......	....	......	.....	......	514	......
20ccc	9/ 2/48	442	74	....	....	....	......	......	177	0	....	24	......	......	.....	......	....	......	.....	......	548	......
20ddd	9/ 2/48	840	75	....	....	....	......	......	167	0	....	29	......	......	.....	......	....	......	.....	......	584	......
34add	9/ 3/48	510	75	....	50	11	32		152	0	67	22	.2	16	273	.37	170	46	.....	......	471	......
(D-12-10)29abb	8/ 4/42	290	78	....	36	7.0	33		181	0	18	14	.8	3.0	198	.27	119	......	.....	......	360	......
33ddd	9/10/52	600	81	36	....	....	......	......	179	0	....	11	......	......	.....	......	....	......	.....	......	338	......
	8/ 4/53		.....	....	....	....	......	......	180	0	....	12	......	......	.....	......	....	......	.....	......	345	......
	8/26/54		82	37	34	4.7	36		179	0	15	11	.6	4.0	230	.31	104	0	43	1.5	353	......
	7/18/55		81	....	....	....	......	......	180	0	....	12	......	......	.....	......	....	......	.....	......	351	7.2
	6/19/56		81	....	....	....	......	......	173	0	....	12	......	......	.....	......	100	0	.....	......	345	7.7
	5/ 9/57		83	....	....	....	......	......	177	0	....	12	......	......	.....	......	105	0	.....	......	346	7.5
(D-14-10)25caa	4/16/40	400	90	....	118	8.3	113		139	......	317	90	.9	......	715	......	329	......	.....	......	1,080	......
(D-14-11)9dbd	4/16/54	325	.....	34	37	1.5	36		181	0	7.2	9	.8	8.5	223	.30	98	0	45	1.6	338	......
33ccc	7/18/55	712	87	39	28	7.1	34		166	0	18	11	.6	2.3	222	.30	99	0	43	1.5	336	7.1
(D-14-12)17bb	3/15/40	113	.....	....	45	29	76	......	316	......	67	45	1.5	......	420	......	231	......	.....	......	750	......
(D-15-10)28cdd	7/18/55	640	84	50	6	3.1	65		161	0	2.3	19	1.8	2.3	228	.31	28	0	84	5.4	344	7.2
35aa	3/14/40	350	.....	....	26	6.1	43	......	160	0	29	15	0	......	198	......	90	......	.....	......	320	......

Table 5.--Partial chemical analyses of ground water, Avra and Altar Valleys, Pima County, Ariz.

[Analytical results in parts per million except as indicated; analysis by University of Arizona]

Well number	Date of collection	Depth (feet)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Hardness as $CaCO_3$
(D-11-10)8aad	4/51	650	60	11	63	207	0	114	30	0.3	195
8ddd	9/51	443	68	8	53	202	0	96	34	......	202
12ccc	9/51	501	60	4	63	183	0	99	39	......	166
13aaa	9/51	520	60	8	41	171	0	81	32	......	185
14dab	12/55	395	74	18	25	220	Trace	70	44	......	262
22add	6/49	600	105	0	90	224	Trace	200	46	.7	257
22ddd	9/51	375	68	11	92	234	0	164	40	......	214
23ddd	12/61	370	59	11	86	230	0	146	28	.4	193
24aaa	9/51	500	68	8	60	198	0	109	38	......	202
24bda	9/51	348	60	4	57	190	0	83	32	......	166
25dda	6/51	600	83	8	81	237	0	200	30	......	240
26bcb	12/49	400	53	4	149	256	0	205	34	.2	149
27cdc	9/51	310	45	4	40	181	0	25	28	......	128
28bad	8/65	700	32	9	63	176	0	44	92	.4	192
(D-11-11)16cdd	7/44	538	50	2	40	153	0	34	28	......	134
17ddd	9/51	500	53	4	21	144	0	30	30	.4	149
18ddd	7/44	596	53	1	51	169	0	64	21	......	137
20ccc	5/64	442	58	9	40	186	0	76	20	......	183
28acd	9/51	500	75	11	21	168	0	81	81	......	231
28ddd	9/51	500	68	8	18	151	0	77	24	......	202
31add	9/51	553	98	4	80	224	0	172	48	......	262
32add	3/55	400	118	21	11	238	0	125	56	.2	385
33bbd	12/61	385	52	11	49	171	0	109	20	.3	175
33daa	8/65	440	66	19	34	191	0	80	36	.2	188
34add	9/51	510	68	8	24	154	0	73	34	......	202
34ddd	9/51	492	68	8	33	161	0	87	34	......	202
35adc	12/56	502	46	12	30	171	0	40	34	......	166
35ddd	5/64	500	56	7	69	161	0	122	32	......	171
(D-12-10)3ccc	9/61	710	24	9	33	161	0	8	16	......	96
3dcd	6/51	520	30	0	37	171	0	Trace	10	......	75
4daa	11/53	402	38	0	30	144	0	20	14	......	94
24cdd	6/51	400	30	0	39	181	0	Trace	10	......	75
30bbc1	1/62	502	88	16	95	176	0	79	148	......	286

Table 5.--Partial chemical analyses of ground water, Avra and Altar Valleys, Pima County, Ariz. — Continued

Well number	Date of collection	Depth (feet)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Hardness as $CaCO_3$
(D-12-10)30bbc2	1/62	302	86	13	102	176	0	82	143	......	269
32ddd	6/51	580	38	0	34	183	0	Trace	12	......	94
33cdc	6/63	1,900	30	3	37	161	2	10	12	0.4	87
33ddd	6/57	600	45	0	23	176	0	Trace	14	......	113
(D-12-11)7cdd	8/65	606	37	9	72	215	0	50	36	.4	130
12dda	4/51	555	113	8	61	224	0	191	44	......	315
18dcc	12/56	385	61	19	53	183	0	20	124	.4	233
18dcd	9/51	474	45	4	33	190	0	Trace	30	......	128
20dda	12/55	677	29	6	62	190	0	15	42	......	98
(D-13-10)4ddd	6/51	600	30	0	39	178	0	Trace	10	......	75
5ddd	5/64	587	33	8	42	173	0	34	18	......	149
8ada	12/55	600	31	7	44	183	0	15	24	......	108
9ddd	6/51	700	45	0	23	181	0	Trace	10	......	113
15ddd	12/55	814	29	7	46	183	0	15	26	......	103
16ddd	12/55	600	29	8	41	183	0	15	22	......	106
20ccd	12/55	....	74	22	113	146	0	140	84	......	278
25dcc	12/55	685	33	6	41	185	0	15	22	......	108
(D-13-11)11acc	12/59	520	61	29	80	204	0	180	64	3.2	277
18dd	12/55	....	23	8	41	183	0	Trace	20	......	92
34cdd	3/64	560	32	7	43	181	0	22	20	.3	106
(D-14-10)23dca	1/56	400	47	24	85	207	Trace	138	70	....	217
25caa	5/61	400	131	9	150	137	0	410	107	1.8	365
(D-14-11)2ccc	4/61	582	27	5	32	146	2	9	18	0	89
7bad	1/56	700	41	9	67	171	0	45	60	......	137
13ccc	1/55	604	23	Trace	53	166	Trace	Trace	30	......	60
19bab	12/57	411	32	6	46	165	0	44	19	......	103
29ddd	3/53	542	45	15	7	142	0	Trace	40	......	175
33dcd	1/56	670	25	6	41	183	0	Trace	22	......	87
34bbc	1/56	535	23	7	39	171	0	Trace	20	......	86
(D-14-12)34cc	1/56	322	30	24	122	451	Trace	175	110	1.0	342
(D-15-10)28cdd	7/64	640	5	2	64	132	7	17	16	1.3	21
33bcc	7/64	710	3	1	66	98	24	14	16	1.3	14
33cbc	7/64	783	2	1	48	39	29	17	12	1.3	9

Table 5.--Partial chemical analyses of ground water, Avra and Altar Valleys, Pima County, Ariz.—Continued

Well number	Date of collection	Depth (feet)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Hardness as $CaCO_3$
(D-15-10)33dbc	7/64	616	20	2	44	127	2	19	20	1.3	60
(D-15-11)5ccd	5/65	712	30	4	42	166	0	22	16	.6	94
12dca	1/56	550	23	8	41	178	0	Trace	22	....	91
(D-16-9) 15dbb	6/45	300	17	2	69	181	0	10	30	.4	51
28dac	....	1,007	18	2	49	154	0	0	26	.2	51
29caa	3/31	....	15	8	63	185	0	Trace	38	....	70
(D-16-10)4bad	3/47	400	30	5	38	184	0	11	7	....	96
10ddd	6/51	351	53	4	35	190	0	10	36	....	149
19cca	6/51	180	60	4	14	183	0	25	14	....	166
35ccb	3/57	830	52	14	32	224	0	20	36	.3	190
(D-17-9) 23ada	6/51	....	53	8	11	195	0	10	10	....	166
35aac	4/43	416	58	0	14	190	0	Trace	14	....	146
(D-17-10)10ccc	1/56	905	53	15	37	244	0	15	40	....	195
(D-18-9) 11baa	5/61	....	43	11	18	156	0	50	8	.6	152
30ada	6/51	425	38	4	28	176	0	15	10	....	111
(D-19-8) 13cad	6/51	....	75	4	9	224	0	25	10	....	204
(D-19-9) 3acb	6/51	376	53	8	21	168	0	Trace	14	....	166
15ada	6/51	571	38	4	23	176	0	Trace	10	....	111
(D-21-8) 27ada	6/51	400	30	8	37	198	0	Trace	16	....	110

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No.

20. Hydrologic and drill-hole data, San Xavier Indian Reservation and vicinity, Pima County, Arizona, by L. A. Heindl and N. D. White: 48 p., 3 figs., 1965.

21. Basic hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona, and Hidalgo County, New Mexico, by N. D. White and C. R. Smith: 42 p., 4 figs., 1965.

22. Bibliography of U.S. Geological Survey water-resources reports, Arizona, 1891 to 1965, compiled by the Arizona District, Water Resources Division, U.S. Geological Survey: 59 p., 1965.

No.

23. Geohydrology of the Dateland-Hyder area, Maricopa and Yuma Counties, Arizona, by W. G. Weist, Jr.: 46 p., 8 figs., 1965.

24. Annual report on ground water in Arizona, spring 1964 to spring 1965, by N. D. White and others: p., figs., 1965.

25. An appraisal of the ground-water resources of Avra and Altar Valleys, Pima County, Arizona, by N. D. White, W. G. Matlock, and H. C. Schwalen: 66 p., 12 figs., 1966.